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Early Diagnoses of Autism Spectrum Disorders in Massachusetts Birth Cohorts, 2001–2005

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KEY WORDS

autism spectrum disorders, ASD, early diagnoses, early intervention

ABBREVIATIONS

ASD—autism spectrum disorder
PDD—pervasive developmental disorder
NOS—not otherwise specified
PELL—Pregnancy to Early Life Longitudinal Data System
LBW—low birth weight
aOR—adjusted odds ratio
CI—confidence interval

All authors made substantive intellectual contributions to this article. Susan E. Manning, Carol A. Davin, Karen Clements, and Milton Kotelchuck made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data. All authors contributed to drafting the article or revising it critically for important intellectual content and final approval of the version to be published.

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WHAT'S KNOWN ON THIS SUBJECT: Early identification of autism spectrum disorders and early initiation of developmental services can improve outcomes. The Centers for Disease Control and Prevention estimates that an average of 1 in 110 children aged 8 years have an autism spectrum.

WHAT THIS STUDY ADDS: A total of 1 in 129 children in Massachusetts born between 2001 and 2005 were enrolled in early intervention with an autism spectrum disorder by the age of 36 months. Early autism spectrum disorder diagnoses increased between 2001 and 2005.

abstract

OBJECTIVE: We examined trends in autism spectrum disorder diagnoses by age 36 months (early diagnoses) and identified characteristics associated with early diagnoses.

METHODS: Massachusetts birth certificate and early-intervention program data were linked to identify infants born between 2001 and 2005 who were enrolled in early intervention and receiving autism-related services before age 36 months (through December 31, 2008). Trends in early autism spectrum disorders were examined using Cochran-Armitage trend tests. χ^2 Statistics were used to compare distributions of selected characteristics for children with and without autism spectrum disorders. Multivariate logistic regression analyses were conducted to identify independent predictors of early diagnoses.

RESULTS: A total of 3013 children (77.5 per 10 000 study population births) were enrolled in early intervention for autism spectrum disorder by age 36 months. Autism spectrum disorder incidence increased from 56 per 10 000 infants among the 2001 birth cohort to 93 per 10 000 infants in 2005. Infants of mothers younger than 24 years of age, whose primary language was not English or who were foreign-born had lower odds of an early autism spectrum disorder diagnosis. Maternal age older than 30 years was associated with increased odds of an early autism spectrum disorder diagnosis. Odds of early autism spectrum disorders were 4.5 (95% confidence interval: 4.1–5.0) times higher for boys than girls.

CONCLUSIONS: Early autism spectrum disorder diagnoses are increasing in Massachusetts, reflecting the national trend observed among older children. Linkage of early-intervention program data with population-based vital statistics is valuable for monitoring autism spectrum disorder trends and planning developmental and educational service needs. *Pediatrics* 2011;127:1043–1051

Autism spectrum disorders (ASDs), including autistic disorder, Asperger's disorder, and pervasive developmental disorder (PDD), not otherwise specified (NOS), are typically lifelong neurodevelopmental disorders characterized by impairments in social function, communication, and certain behaviors.[1] Symptoms usually begin before the age of 3 years. Autism is an important and growing public health concern, with substantial impacts on those affected and their families. Early identification of ASDs and initiation of developmental services can improve developmental and educational outcomes.[2–13] Estimates of the incidence of ASDs and identification of characteristics predictive of early diagnoses could facilitate case finding and inform service provision. However, state-level, population-based estimates of ASD occurrence among children aged birth to 3 years are lacking.

Autistic disorder can be reliably diagnosed in children as young as 2 years of age, but diagnoses of Asperger's disorder and PDD-NOS are more difficult until later in childhood.[14] Routine developmental screening with appropriate diagnostic follow-up can increase early diagnosis of ASDs. In 2007, the American Academy of Pediatrics recommended ASD surveillance at every well-child visit and ASD screening at 18 and 24 months of age and whenever developmental concerns arise.[15]

Mounting evidence suggests that early initiation of intensive intervention can improve developmental outcomes for children with ASDs.[2–13] In 2001, the National Research Council, Committee on Educational Interventions for Children With Autism recommended that educational services, including a minimum of 25 hours per week of "systematically planned and developmentally appropriate educational activity toward identified objectives," should be initiated as soon as autism is suspected.[16]

Treatment for ASDs for children through 3 years of age is available through state-coordinated early-intervention services, mandated under Part C of the Individuals With Disabilities Education Act (1997). In 1998, Massachusetts created the Early Intervention Specialty Services Program to address the unique needs of children with ASDs. During the period covered in this analysis, Massachusetts children who screened positive for ASDs on the Modified Checklist for Autism in Toddlers[17] (administered by a physician, a licensed clinical psychologist, or a licensed mental health counselor approved by the Massachusetts Department of Public Health for this purpose), and who were confirmed to have been referred for additional evaluation, were eligible for ASD specialty services. Approaching $11 million annually, the cost of ASD specialty services in Massachusetts has been increasing. Information on trends and patterns of early ASD diagnoses in the Commonwealth can inform planning for future developmental and educational service needs, including special education. The objectives of this analysis were to examine trends in ASD diagnoses in the Massachusetts Early Intervention Program, overall, and by selected characteristics and to identify characteristics associated with early ASD diagnosis.

METHODS

Data Source and Linkage

A data-use and confidentiality agreement was executed with the Massachusetts Department of Public Health to perform the analyses on behalf of the Massachusetts Early Intervention Program. Data were derived from the Massachusetts Pregnancy to Early Life Longitudinal Data System (PELL), a public-private partnership between the Massachusetts Department of Public Health, the Boston University School of Public Health, and the Centers for Disease Control and Prevention. PELL is a relational data system composed of individual data sets that are linked together by randomly generated unique identification numbers for mothers and infants.

A 9-step algorithm was used to match early-intervention program data with resident birth certificate records on various combinations of a child's first and last names, mother's last name, child's date of birth, mother's date of birth, child's gender, zip code, and Soundex, a SAS function used to combine alpha-numeric data on the basis of similar but not exact sounds. The linkage was performed with LinkPro (InfoSoft, Winnipeg, Manitoba, Canada). Early-intervention records missing data on key linkage variables were excluded, as were records of children who were adopted. The overall linkage rate of early-intervention records to a birth certificate was 87.3%. For analysis, records were stripped of all identifying information.

Study Population

Children with ASDs were defined as those with a documented diagnosis of autistic disorder (*International Classification of Diseases* code 299.00), Asperger's disorder (code 299.80), PDD-NOS (code 299.90), or "autism spectrum disorder" in the early-intervention database and/or an early-intervention specialty services program claim indicating that they had received autism-related services. "Early ASD diagnosis" refers to children enrolled in early intervention for ASD before the age of 36 months.

For these analyses, we examined data for 390 567 in-state, live births to Massachusetts resident mothers between 2001 and 2005. We included only those children who had the opportunity to receive an ASD diagnosis before their third birthday. We therefore excluded children known to have died before the age of 3 years ($n = 1923$). The analysis study population consisted of 388 644 children (3013 with early diagnoses of ASDs and 385 631 without documented ASDs).

Predictors

Maternal and paternal demographic characteristics were derived from birth certificates. Age was categorized into 7 groups. Race and Hispanic ethnicity were combined into the following 4 categories: Hispanic of any race; non-Hispanic black; non-Hispanic other, including non-Hispanic Asian/Pacific Islanders; and non-Hispanic white. Education was categorized as some high school, high school graduate, some college (<4 years), and 4 years of college or more. Place of birth was coded as US born or foreign-born and language preference as English or not English. Marital status and parity (1, 2, or ≥3 previous live births) also were included. Maternal delivery payer source was derived from the infant's hospital discharge record. Infant characteristics also were derived from birth certificates and included gender, birth weight (≥2500 g versus <2500 g [low birth weight {LBW}]), plurality (singleton versus multiples), and prematurity (≥37 weeks [term] versus <37 weeks [preterm]).

Data Analysis

Trends in early ASD diagnoses (numbers of diagnoses per 10 000 eligible births) were examined for 2001–2005 birth cohorts, overall and by gender, race/ethnicity, and diagnosis type. Cochran-Armitage tests were used to assess significantly increasing or decreasing trends. Bivariate and multivariate analyses were conducted combining 2001–2005 data. Bivariate analyses using χ^2 statistics compared selected maternal, paternal, and infant characteristics for children with or without early diagnoses of ASDs, overall and stratified by infant gender.

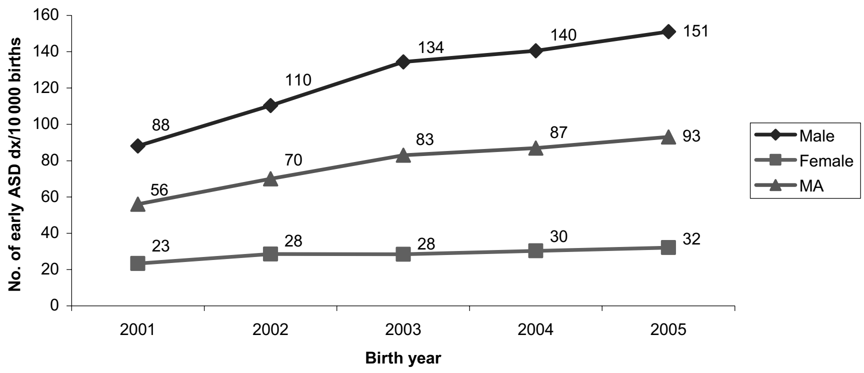

FIGURE 1
Trends in early diagnoses of ASDs in Massachusetts (MA) among children born between 2001 and 2005 and receiving early-intervention services through 2008, overall and by infant gender. All trends are statistically significantly increasing at the $\alpha = 0.05$ level (boys $P < .0001$, girls $P = .025$, Massachusetts $P < .0001$), based on the Cochran-Armitage trend test.

Statistical significance was inferred at $P < .05$ in trend and bivariate analyses. Multivariate logistic regression analyses examined the independent associations of selected characteristics with early ASD diagnoses. Crude and adjusted odds ratios (aORs) and 95% confidence intervals (CIs) were calculated. All variables found to be significant in bivariate analyses were included in multivariate models, except for paternal race/ethnicity because of an observed strong correlation with maternal race/ethnicity. All analyses were conducted using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

Among 388 644 children born in Massachusetts between 2001 and 2005 who survived to 3 years of age, 3013 (78 per 10 000 births) were enrolled in early intervention for ASDs by 36 months of age. ASD incidence increased from 56 per 10 000 children for the 2001 birth cohort to 93 per 10 000 for the 2005 cohort (Fig 1). Among boys, early ASD diagnoses increased more than 70%, from 88 per 10 000 children for the 2001 birth cohort to 151 per 10 000 for the 2005 cohort. ASD diagnoses among girls increased by only 39% over the same time period (from 23 per 10 000 to 32 per 10 000 children). Although the 2001 birth cohort showed racial/ethnic disparities (non-Hispanic white children had the highest incidence [63 per 10 000], 29% higher than non-Hispanic black children [49 per 10 000], 62% higher than non-Hispanic other, including non-Hispanic Asian/Pacific Islanders [39 per 10 000], and 90% higher than Hispanic children of any race [33 per 10 000]), these disparities substantially lessened among the 2005 cohort (96 per 10 000 among Hispanics of any race, 95 per 10 000 among non-Hispanic whites, 87 per 10 000 among non-Hispanic blacks, and 80 per 10 000 among non-Hispanic other, including non-Hispanic Asian/Pacific Islanders) (Fig 2).

Figure 3 shows trends by diagnosis type. PDD-NOS increased from 23 per 10 000 to 37 per 10 000 children ($P < .001$), and ASDs (NOS) increased from 15 per 10 000 to 33 per 10 000 children ($P < .001$) from 2001 to 2005, whereas diagnoses of autism remained relatively stable ($P = .269$).

Table 1 compares maternal, paternal, and infant characteristics of children with or without early ASD diagnoses. Significant differences were observed for all characteristics examined. Given the significantly higher occurrence of

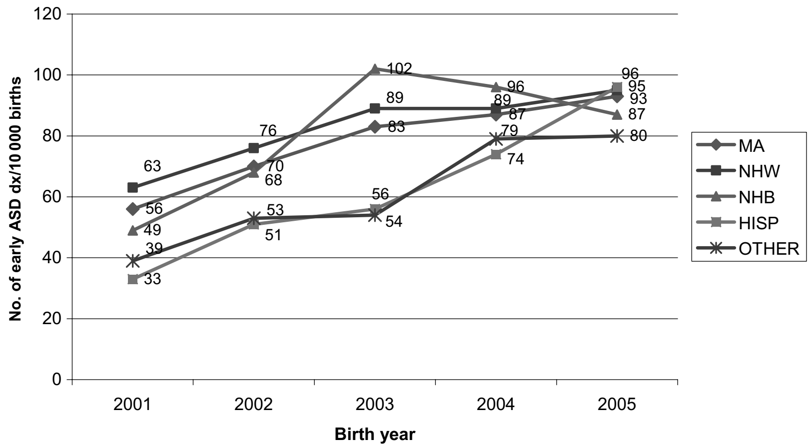

FIGURE 2

Trends in early diagnoses of ASDs in Massachusetts (MA) among children born between 2001 and 2005 and receiving early-intervention services through 2008, overall and by race/ethnicity. All trends are statistically significantly increasing at the $\alpha = 0.05$ level, based on the Cochran-Armitage trend test. HISP indicates Hispanic; NHB, non-Hispanic black; NHW, non-Hispanic white; OTHER, non-Hispanic other, including non-Hispanic Asian/Pacific Islanders.

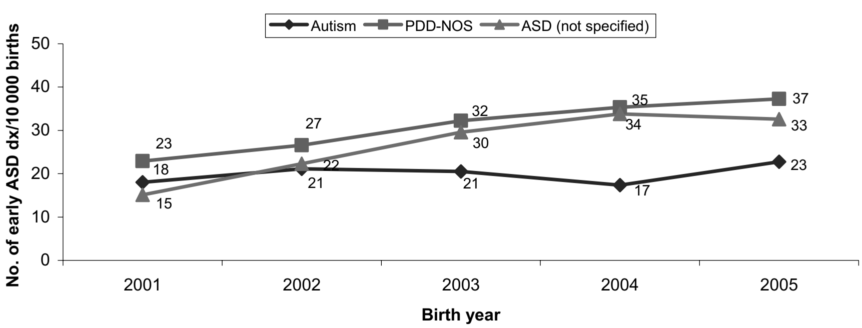

FIGURE 3

Trends in early diagnoses of ASDs in Massachusetts among children born between 2001 and 2005 and receiving early-intervention services through 2008, by diagnosis type. Trends for PDD-NOS and ASD-NOS are statistically significantly increasing at the $\alpha = 0.05$ level, based on the Cochran-Armitage trend test. No significant increase or decrease for autism diagnoses was observed.

early ASD diagnoses among boys, characteristics of children with or without ASD were further stratified by gender and compared (Table 2). Birth weight was the only variable that differed significantly between boys and girls with ASDs (among girls, 15.7% were LBW versus only 11.0% among boys, $P = .002$).

Table 3 presents crude ORs and aORs for associations between selected characteristics and early ASD diagnoses. Controlling for maternal, paternal, and infant characteristics, relative to mothers aged 25 to 29 years, odds of early ASD diagnoses were lower for infants of mothers younger than age 20 years (aOR: 0.64 [95% CI: 0.47–0.87]) or 20 to 24 years (aOR: 0.83 [95% CI: 0.70–0.98]) and higher for mothers aged 30 years and older (aged 30–34: aOR: 1.27 [95% CI: 1.13–1.42]; aged 35–39: aOR: 1.39 [95% CI: 1.21–1.59; aged 40–44: aOR: 1.52 [95% CI: 1.23–1.88]; aged ≥45: aOR: 2.03 [95% CI: 1.11–3.69]). The odds of early ASD diagnoses were lower for children of mothers with 4 or more years of college education compared with high school graduates (aOR: 0.85 [95% CI: 0.75–0.96]), who spoke a non-English primary language compared with English (aOR: 0.68 [95% CI: 0.56–0.81]), who were foreign born compared with US born (aOR: 0.82 [95% CI: 0.72–0.93]), and who were not primiparous. Odds of early ASD diagnoses were higher for boys (aOR: 4.49 [95% CI: 4.06–4.95]), those with LBW (aOR: 1.26 [95% CI: 1.07–1.47]), multiples (aOR: 1.90 [95% CI: 1.63–2.21]), or those born preterm (aOR:1.18 [95% CI: 1.04–1.35]). Neither paternal age nor paternal education was independently associated with ASDs.

DISCUSSION

Our findings indicate that 1 of every 129 children born in Massachusetts between 2001 and 2005 were enrolled in early intervention with an ASD by 36 months of age. Early ASD diagnoses increased from 1 in 178 for the 2001 birth cohort to 1 in 108 for the 2005 birth cohort. This finding is comparable to the recent estimate based on parent reports in the National Survey of Children's Health that 1 in 91 children aged 3 to 17 years in the US has an ASD[18] and updated surveillance estimates from the Autism and Developmental Disabilities Monitoring Network of 1 in 110 children aged 8 years having an ASD.[19] Given that the average age of diagnosis of ASDs is 41 to 60 months,[19] this analysis is an underestimate of total ASD burden because we would expect additional children to be diagnosed after age 3 years.

Early ASD diagnoses in Massachusetts have increased 66% from 2001 to 2005. This finding is consistent with previous studies that suggest ASD prevalence among older children is increasing.[20–33] Much of the increase observed in Massachusetts is driven by the significant increase in diagnoses among boys, which increased 72%, compared with the lower increase of 39% among girls. Substantial differences in early ASD diagnoses were observed by race/ethnicity among the 2001 birth cohort, with non-Hispanic white children having the highest incidence; however, these racial/ethnic differences essen-

TABLE 1 Selected Maternal, Paternal, and Infant Characteristics of Children With or Without Early Diagnoses of ASDs, 2001–2005 Massachusetts Birth Cohorts

Maternal and Infant Characteristics	Children With Early Diagnosis of ASDs		Children Without Early Diagnosis of ASDs		P[a]	Cumulative Incidence[b]
	n	%	*n*	%		
Total	3013	100	385 631	100		77.5
Maternal characteristics						
Race/ethnicity					<.001	
Non-Hispanic white	2267	75.3	274 396	71.2		81.9
Non-Hispanic black	236	7.8	29 112	7.6		80.4
Hispanic	301	10.0	47 888	12.4		62.5
Other	208	6.9	33 771	8.8		61.2
Age, y					<.001	
<20	104	3.5	23 122	6.0		44.8
20–24	334	11.1	57 948	15.0		57.3
25–29	612	20.3	89 354	23.2		68.0
30–34	1095	36.3	126 788	32.9		85.6
35–39	682	22.6	72 128	18.7		93.7
40–44	168	5.6	15 470	4.0		107.4
≥45	18	0.6	805	0.2		218.7
Education					<.001	
Some high school	203	6.7	39 855	10.3		50.7
High school graduate	730	24.2	97 089	25.2		74.6
Some college	731	24.3	84 052	21.8		86.2
≥4 years of college	1349	44.8	164 619	42.7		81.3
Marital status					<.001	
Married	2267	75.2	277 164	71.9		81.1
Not married	746	24.8	108 434	28.1		68.3
Primary language					<.001	
English	2802	93.0	342 261	88.9		81.2
Not English	210	7.0	42 960	11.2		48.6
Nativity					<.001	
US born	2353	78.1	281 089	72.9		83.0
Foreign born	660	21.9	104 512	27.1		62.8
Parity					<.001	
1	1409	46.8	168 882	43.9		82.7
2	1058	35.2	133 649	34.7		78.5
≥3	541	18.0	82 288	21.4		65.3
Delivery payer source					<.001	
Private	2136	70.9	253 562	65.8		83.4
Public	849	28.2	127 589	33.1		66.1
Other	28	0.9	4266	1.1		65.2
Paternal characteristics						
Race/ethnicity					<.001	
Non-Hispanic white	2222	77.6	265 023	73.6		83.1
Non-Hispanic black	222	7.8	28 376	7.9		77.6
Hispanic	140	4.9	22 631	6.3		61.5
Other	279	9.8	43 984	12.2		63.0
Age, y					<.001	
<20	38	1.4	7693	2.3		49.2
20–24	184	6.8	33 437	9.9		54.7
25–29	445	16.5	62 910	18.6		70.2
30–34	875	32.4	109 230	32.2		79.5
35–39	716	26.5	81 062	23.9		87.6
40–44	310	11.5	32 429	9.6		94.7
≥45	133	4.9	12 385	3.7		106.3
Education					<.001	
Some high school	347	11.5	59 517	15.5		58.0
High school graduate	892	29.6	109 047	28.3		81.1
Some college	501	16.6	61 548	16.0		80.7
≥4 years of college	1270	42.2	154 626	40.2		81.5
Infant characteristics						
Infant gender					<.001	
Male	2472	82.0	196 008	50.8		124.5
Female	541	18.0	189 607	49.2		28.5
Birth weight					<.001	
≥2500 g	2653	88.2	357 429	92.9		73.7
<2500 g (LBW)	356	11.8	27 496	7.1		127.8
Plurality					<.001	
Singleton	2702	89.7	368 246	95.5		72.8
Twin or higher order	311	10.3	17 369	4.5		175.9
Prematurity					<.001	
Term (≥37 wk)	2520	83.8	345 211	89.7		72.5
Preterm (<37 wk)	487	16.2	39 498	10.3		121.8

Missing values were excluded from the tables and from χ^2 calculations.

[a] χ^2 Test of the difference in distribution for each independent variable between children with and without ASDs.

[b] Cumulative incidence equals the number of early ASD diagnoses per 10 000 births in the study population.

tially disappeared among the 2005 birth cohort. There were significant increases in PDD-NOS and ASD-NOS from 2001 to 2005; however, the proportion of autism diagnoses did not increase significantly.

The increasing trend in ASD diagnoses in Massachusetts, particularly among the subtypes PDD-NOS and ASD-NOS, and the decreasing racial/ethnic disparities might reflect, at least in part, increased efforts by the Massachusetts Department of Public Health to promote the early identification and referral of all children with ASDs in racially/ethnically diverse areas of the state. The increasing ASD trend also might reflect the success of national efforts such as the Centers for Disease Control and Prevention's "Learn the Signs, Act Early" campaign and the American Academy of Pediatrics' recommendations to providers regarding ASD screening.[15] Other factors that might contribute to increases in ASDs include increased provider and public awareness about autism as a result of increased media attention and advocacy efforts. Although the exact reason is unknown, ASD diagnoses are rising in national and state analyses.

The finding that male gender was a strong predictor of an early ASD diagnosis is consistent with previous studies that demonstrated higher rates of ASDs among boys, with boy-to-girl ratios generally around 4 to 1.[18,19,23,34,35] Infants who were LBW or preterm also had higher odds of an early ASD diagnoses than their normal-weight and term counterparts. These findings are consistent with other studies[36,37] showing that children born preterm and LBW are at greater risk of being diagnosed with autism than are children born at term, particularly those with extremely low gestational age (<28 weeks). Furthermore, preterm or LBW infants are more likely to be closely monitored for developmental issues

TABLE 2 Selected Maternal, Paternal, and Infant Characteristics of Children With or Without Early Diagnoses of ASDs by Infant Gender, 2001–2005 Massachusetts Birth Cohorts

Characteristics	Boys			Girls			Boy:Girl Ratio	P[b]
	With ASDs, %	Without ASDs, %	ASD Cumulative Incidence[a]	With ASDs, %	Without ASDs, %	ASD Cumulative Incidence[a]		
Total			125			28	4.5	
Maternal race/ethnicity								.232
Non-Hispanic white	75.4	71.2	132	74.5	71.3	30	4.4	
Non-Hispanic black	7.8	7.6	127	8.1	7.5	31	4.1	
Hispanic	10.3	12.4	104	8.7	12.5	20	5.2	
Other	6.5	8.8	92	8.7	8.7	28	3.3	
Maternal age, y								.161
<20	3.7	5.9	78	[c]	[c]	[c]	[c]	
20–24	11.5	15.0	95	9.2	15.0	18	5.3	
25–29	19.8	23.3	106	22.6	23.0	28	3.8	
30–34	36.7	32.9	139	34.8	32.9	30	4.6	
35–39	22.2	18.6	148	24.8	18.8	37	4.0	
40–44	5.5	4.0	170	6.1	4.1	43	4.0	
≥45	0.7	0.2	386	[c]	[c]	[c]	[c]	
Maternal education								.415
Some high school	6.9	10.3	84	5.9	10.4	16	5.3	
High school graduate	24.6	25.1	122	22.7	25.3	26	4.7	
Some college	24.4	21.9	139	23.5	21.7	31	4.5	
≥4 years of college	44.1	42.7	129	47.9	42.7	32	4.0	
Marital status								.746
Not married	24.9	28.2	110	24.2	28.1	25	4.4	
Married	75.1	71.8	130	75.8	71.9	30	4.3	
Maternal primary language								.749
English	93.0	88.8	130	93.4	88.9	30	4.3	
Not English	7.0	11.2	79	6.7	11.1	17	4.6	
Maternal nativity								.606
US born	78.3	72.8	134	77.3	73.0	30	4.5	
Foreign born	21.7	27.2	100	22.7	27.0	24	4.2	
Paternal age, y								.414
<20	1.6	2.3	91	[c]	[c]	[c]	[c]	
20–24	6.9	9.9	89	6.5	9.9	19	4.7	
25–29	16.7	18.8	113	15.4	18.3	24	4.7	
30–34	32.5	32.1	129	32.1	32.3	29	4.4	
35–39	26.1	23.8	139	28.5	24.0	34	4.1	
40–44	11.5	9.5	153	11.5	9.6	34	4.5	
≥45	4.8	3.6	167	[c]	[c]	[c]	[c]	
Parity								.799
1	47.0	44.0	133	46.0	43.8	30	4.4	
2	34.9	34.7	125	36.4	34.8	30	4.2	
≥3	18.1	21.4	106	17.6	21.4	23	4.6	
Delivery payer source								.144
Private	71.0	65.7	134	70.6	65.9	30	4.5	
Public	28.3	33.2	106	27.7	33.0	24	4.4	
Other	0.8	1.1	84	1.7	1.1	44	1.9	
Birth weight								.002
≥2500 g	89.0	93.4	119	84.3	92.3	26	4.6	
<2500 g	11.0	6.6	207	15.7	7.7	58	3.6	
Plurality								.113
Singleton	90.1	95.6	117	87.8	95.4	26	4.5	
Twin or higher order multiple	9.9	4.4	278	12.2	4.6	75	3.7	
Prematurity								.475
Term (≥37 wk)	84.0	89.3	117	82.8	90.2	26	4.5	
Preterm (<37 wk)	16.0	10.7	185	17.2	9.8	50	3.7	

[a] Cumulative incidence equals the number of early ASD diagnoses per 10 000 births in the study population.
[b] χ^2 Comparing distributions of maternal and infant characteristics for boys with ASDs versus girls with ASDs.
[c] Suppressed because of a small cell size and for complementary cell suppression.

and would therefore be more likely to be diagnosed with ASDs at an early age. We also observed higher odds of early ASDs among multiples. It is unclear whether this finding is attributed to the higher likelihood that multiples are preterm and/or LBW or whether the multiple birth itself, or factors related to the multiple birth (eg, fertility medications or assisted reproductive technologies), plays a role. Similar to what has been observed in other studies,[38,39] older maternal age was found to be associated with increased risk of early ASDs, and a dose-response effect was observed with increasing maternal age. Maternal factors that were associated with a lower odds of ASDs were young maternal age (<25 years), having a primary language other than English, and being foreign born. Women with these factors might have a decreased awareness of the early warning signs of ASDs and be less likely to initiate the appropriate screening, diagnosis, and treatment in a timely manner. In contrast to studies that observed an effect of advancing paternal age on ASD risk,[38,40] we observed no independent association after controlling for maternal and infant characteristics, although the crude analysis did show this pattern.

The finding that a higher proportion of girls than boys with ASDs were LBW is consistent with results from a study by Schendel and Bhasin,[41] which demonstrated a twofold increased risk of autism among LBW infants, independent of other birth and demographic factors, but a higher risk for LBW girls than for LBW boys. Our findings are in line with the hypothesis that gender differences might exist in the etiologic pathway to autism.

The direction of effect for our maternal race and education variables changed between unadjusted and adjusted analyses. To explore this further, we reran our multivariate analysis and in-

TABLE 3 Crude ORs and aORs[a] for the Associations Between Selected Maternal, Paternal, and Infant Characteristics and Early ASD Diagnoses, 2001–2005 Massachusetts Birth Cohorts

	Crude OR	95% CI	aOR[a]	95% CI
Maternal characteristics				
Race/ethnicity				
Non-Hispanic white	Reference	—	Reference	—
Non-Hispanic black	0.98	(0.86–1.12)	1.18	(1.00–1.40)
Hispanic	0.76	(0.68–0.86)	1.25	(1.06–1.46)
Other	0.75	(0.65–0.86)	1.01	(0.85–1.20)
Age, y				
<20	0.66	(0.53–0.81)	0.64	(0.47–0.87)
20–24	0.84	(0.74–0.96)	0.83	(0.70–0.98)
25–29	Reference	—	Reference	—
30–34	1.26	(1.14–1.39)	1.27	(1.13–1.42)
35–39	1.38	(1.24–1.54)	1.39	(1.21–1.59)
40–44	1.59	(1.34–1.88)	1.52	(1.23–1.88)
≥45	3.27	(2.03–5.24)	2.03	(1.11–3.69)
Education				
Some high school	0.68	(0.58–0.79)	0.91	(0.75–1.11)
High school graduate	Reference	—	Reference	—
Some college	1.16	(1.04–1.28)	1.01	(0.90–1.13)
≥4 years of college	1.09	(1.00–1.19)	0.85	(0.75–0.96)
Marital status				
Married	Reference	—	Reference	—
Not married	0.84	(0.77–0.91)	1.07	(0.95–1.21)
Primary language				
English	Reference	—	Reference	—
Not English	0.60	(0.52–0.69)	0.68	(0.56–0.81)
Nativity				
US born	Reference	—	Reference	—
Foreign born	0.76	(0.69–0.82)	0.82	(0.72–0.93)
Parity				
1	Reference	—	Reference	—
2	0.95	(0.88–1.03)	0.84	(0.77–0.91)
≥3	0.79	(0.71–0.87)	0.63	(0.56–0.70)
Delivery payer source				
Private	Reference	—	Reference	—
Public	0.79	(0.73–0.86)	1.09	(0.96–1.23)
Other	0.78	(0.54–1.13)	0.98	(0.66–1.45)
Paternal characteristics				
Age, y				
<20	0.70	(0.50–0.97)	0.80	(0.54–1.19)
20–24	0.78	(0.66–0.92)	0.83	(0.68–1.01)
25–29	Reference	—	Reference	—
30–34	1.13	(1.01–1.27)	1.04	(0.92–1.19)
35–39	1.25	(1.11–1.41)	1.10	(0.96–1.27)
40–44	1.35	(1.17–1.56)	1.14	(0.96–1.35)
≥45	1.52	(1.25–1.84)	1.22	(0.98–1.53)
Education				
Some high school	0.71	(0.63–0.81)	0.91	(0.77–1.09)
High school graduate	Reference	—	Reference	—
Some college	1.00	(0.89–1.11)	0.95	(0.85–1.07)
≥4 years of college	1.00	(0.92–1.09)	0.93	(0.83–1.04)
Infant characteristics				
Infant gender				
Male	4.42	(4.03–4.85)	4.49	(4.06–4.95)
Female	Reference	—	Reference	—
Birth weight				
≥2500 g	Reference	—	Reference	—
<2500 g (LBW)	1.74	(1.56–1.95)	1.26	(1.07–1.47)
Plurality				
Singleton	Reference	—	Reference	—
Twin or higher order	2.44	(2.17–2.75)	1.90	(1.63–2.21)
Prematurity				
Term (≥37 wk)	Reference	—	Reference	—
Preterm (<37 wk)	1.69	(1.53–1.86)	1.18	(1.04–1.35)

[a] Adjusted for all other variables simultaneously.

cluded a maternal race/education interaction term, which proved significant. Detailed examination of the interaction (data not provided) revealed both greater heterogeneity and a different pattern in early ASD diagnosis by maternal education levels among children of non-Hispanic blacks; non-Hispanic other, including non-Hispanic Asian/Pacific Islanders; and Hispanic mothers compared with non-Hispanic white mothers. Early ASD diagnosis was less frequent among children of non-Hispanic white mothers with 4 or more years of college compared with high school graduation. In contrast, more early ASD diagnoses occurred among children of non-Hispanic blacks; non-Hispanic other, including non-Hispanic Asian/Pacific Islanders; and, to a lesser extent, mothers who were Hispanics of any race with more education (significantly for non-Hispanic blacks), and fewer diagnoses occurred among those with less education. As a result, proportionately more early ASD diagnoses were observed among children of non-Hispanic blacks and Hispanics of any race versus non-Hispanic white mothers with more education and less early diagnoses were observed among children of non-Hispanic other, including non-Hispanic Asian/Pacific Islanders, versus non-Hispanic white mothers with less education. This finding seems reflective of the historical pattern of greater diagnosis of ASDs among well-educated white parents observed in other studies[18,42] and suggests that efforts to provide ASD services equally across all racial and educational groups have not been fully successful.

Our study has several limitations. Any child receiving autism specialty services was considered to have an ASD, and although the majority of children enrolled in specialty services already had a confirmed ASD diagnosis, confirmation of ASDs was not available for all children; thus, our case definition might be overly inclusive. It is possible that ASDs might have been initially suspected because of the positive initial screen but subsequently ruled out. These factors would lead to an overestimation of early diagnoses of ASDs.

In contrast, these findings might underestimate early ASD diagnoses. Some children with ASDs might not participate in early intervention and would therefore be missed in this study, which used administrative early-intervention data for case ascertainment. Although there are limitations to using administrative data for this purpose, the data are useful for assessing the number of children receiving ASD services and for monitoring trends in service utilization. Furthermore, the percentage of children with ASDs who were not in early intervention is expected to be low because during the study period, public and private health insurance did not cover intensive behavioral services in Massachusetts, and any family choosing not to enroll their child in early intervention either self-paid or opted not to have their child receive autism services. In addition, ascertainment of cases in PELL may be incomplete. PELL does not have information on children who were adopted, who were born in other states, or who were missing information on key variables that prevented linkage. PELL also does not have information on children born in Massachusetts but who moved out of state and were subsequently diagnosed with ASDs elsewhere. Finally, our results provide estimates of early diagnoses of ASDs, and no information is currently available on children diagnosed with ASDs at later ages.

Despite these limitations, this study has a number of important strengths. Linkage of early-intervention program and vital statistics data enables population-based estimates of ASD diagnoses to be made. Because we were able to compile data from multiple years, our analysis was sufficiently powered to conduct multivariate and stratified analyses and assess independent effects of selected factors.

CONCLUSIONS

Early diagnoses of ASDs are increasing in Massachusetts, particularly among boys, reflecting national trends. Our analysis shows that linkage of early-intervention program data and population-based vital statistics data is useful for identifying trends and disparities in early ASD diagnoses. The results of this type of analysis can be used to increase clinician awareness of the early signs of ASDs and inform state early-intervention program efforts to anticipate future service demands and resources needed. These findings also highlight the importance of providing pediatric care in a family-centered medical home to facilitate the early identification, diagnosis, and management of complex medical and developmental disorders like ASDs.

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Early Diagnoses of Autism Spectrum Disorders in Massachusetts Birth Cohorts, 2001 –2005

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