Annual trends in prevalence and incidence of autism spectrum disorders in Manitoba preschoolers and toddlers: 2004–2015

Amani F. Hamad¹ · Silvia Alessi-Severini^{1,2} · Salaheddin M. Mahmud^{1,3,4} · Marni Brownell^{2,3} · I fan Kuo¹

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Abstract

Objectives Autism spectrum disorders (ASD) are among the leading causes of disabilities in children. We examined the annual prevalence and incidence rate of ASD between 2004 and 2015 in children aged 1 to 5 years residing in Manitoba.

Methods A population-based study was conducted using the Manitoba Population Research Data Repository. The study included children aged 1 to 5 years residing in Manitoba between 2004 and 2015. Standard identification algorithm was used to identify ASD cases from hospital abstracts and medical claims. Annual prevalence and incidence rates were calculated for the overall population and then stratified according to sex, region, and socio-economic status (SES). Multivariable negative binomial regression models, adjusted for sex, region, and SES, were used to examine changes in prevalence and incidence over study years.

Results Among children aged 1 to 5 years, 1685 ASD cases were diagnosed between 2004 and 2015. The crude ASD prevalence increased from 0.46% in 2004 to 0.97% in 2015 ($p = 0.002$). The crude incidence rate increased from 0.16% in 2004 to 0.39% in 2015 ($p = 0.002$). The increase in ASD prevalence and incidence was observed in all subgroups based on sex, region, and SES. The adjusted negative binomial model showed an annual relative risk increase, since 2004, for both prevalence and incidence of 1.69 (95% CI 1.56–1.83) and 1.84 (95% CI 1.62–2.09), respectively.

Conclusion During the period from 2004 to 2015, both prevalence and incidence rates of diagnosed ASD in preschoolers and toddlers residing in Manitoba increased significantly.

Résumé

Objectifs Les troubles du spectre de l'autisme (TSA) sont parmi les principales causes de handicap chez les enfants. Nous avons étudié le taux annuel de prévalence et d'incidence des TSA entre les années 2004 et 2015 chez les enfants âgés de 1 à 5 ans résidents du Manitoba.

Méthodes Une étude basée sur une population a été menée à l'aide du Dépôt de données de recherche en santé des populations du Manitoba. L'étude incluait des enfants âgés de 1 à 5 ans qui résidaient au Manitoba entre 2004 et 2015. Un algorithme d'identification standard a servi à identifier les cas de TSA à partir des résumés hospitaliers et des réclamations au titre de frais médicaux. Les taux annuels de prévalence et d'incidence ont été calculés pour l'ensemble de la population, puis stratifiés en fonction du sexe, de la région et du statut socio-économique. Des modèles multivariés de régression binomiale négative ajustés en fonction du sexe, de la région et du statut socio-économique, ont été utilisés pour examiner les changements dans la prévalence et l'incidence sur la période étudiée.

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✉ I fan Kuo
I.Kuo@umanitoba.ca

¹ College of Pharmacy, Rady Faculty of Health Sciences, University of Manitoba, 750 McDermot Avenue, Winnipeg, MB R3E 0T5, Canada

² Manitoba Centre for Health Policy, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Canada

³ Department of Community Health Sciences, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Canada

⁴ Vaccine and Drug Evaluation Centre, University of Manitoba, Winnipeg, Canada

Résultats Parmi les enfants âgés de 1 à 5 ans, 1685 cas de TSA ont été diagnostiqués entre 2004 et 2015. Le taux de prévalence brut des TSA est passé de 0,46 % en 2004 à 0,97 % en 2015 ($p = 0,002$). Le taux d'incidence brut est passé de 0,16 % en 2004 à 0,39 % en 2015 ($p = 0,002$). L'augmentation de la prévalence et de l'incidence des TSA a été observée dans tous les sous-groupes en fonction du sexe, de la région et du statut socio-économique. Le modèle binomial négatif ajusté a montré une augmentation annuelle du risque relatif, depuis 2004, pour la prévalence et l'incidence respectivement de 1,69 (IC à 95% 1,56 – 1,83) et de 1,84 (IC à 95% 1,62 – 2,09).

Conclusion Durant la période allant de 2004 à 2015, les taux de prévalence et d'incidence des enfants d'âge préscolaire et des tout-petits résidant au Manitoba chez qui l'on a diagnostiqué des TSA ont considérablement augmenté.

Keywords Autism spectrum disorders · ASD prevalence · Time trends · Public health monitoring

Mots-clés Troubles du spectre autistique · Prévalence des TSA · Tendances temporelles · Surveillance de la santé publique

Introduction

Autism spectrum disorders (ASD) is a group of neurodevelopmental disorders affecting social communication and social interaction with restricted repetitive patterns of behaviour or activities (American Psychiatric Association 2013). It was first described by Kanner in 1943 and the definition evolved over the years (Kanner 1943). In 2013, the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) formally adopted the term ASD to collectively describe autism, pervasive developmental disorder not otherwise specified, childhood disintegrative disorder, and Asperger's disorder under a uniform set of diagnostic criteria (American Psychiatric Association 2013). The disease burden of ASD is significant, with 52 million cases diagnosed worldwide (Baxter et al. 2015). Among all mental illnesses, ASDs are the leading cause of disability in children younger than 5 years (Baxter et al. 2015).

In the United States, an ASD prevalence of 1.47% was reported in the year 2010 among 8-year-old children. This reveals a significant increase in prevalence over time from 0.66% to 0.90% to 1.13% in 2002, 2006, and 2008, respectively (Christensen 2012). In Canada, the Public Health Agency of Canada's National Autism Spectrum Disorder Surveillance System (NASS) reported a combined ASD prevalence of 1.52% in children aged 5 to 17 years based on 2015 data from six provinces and one territory (Ofner et al. 2018). In the province of Manitoba, which was not included in NASS findings, ASD prevalence was estimated at 0.49% for the period 1996 to 2000 in children aged 5 to 9 years. This estimate increased significantly to 0.88% during the years 2001 to 2005, and to 1.25% during 2009 to 2014 (Brownell et al. 2008; Vehling et al. 2016). The incidence of ASD in the general population is yet to be established. Canada's NASS reported an increase in incidence rate in the province of Quebec from 3.9 per 10,000 in the year 2000 to 19.1 per 10,000 in 2015 (Ofner et al. 2018).

Despite several reports on ASD prevalence in North America, it remains difficult to quantify the trends of the disorder given the limited data years and varied diagnostic criteria of the studies. Moreover, less is known about ASD

prevalence and incidence in younger children. In this study, we examined annual trends in ASD prevalence and incidence in Manitoban children aged 1 to 5 years over the years from 2004 to 2015.

Methods

Study setting and data source

The study was conducted utilizing the Manitoba Population Research Data Repository housed at the Manitoba Centre for Health Policy (MCHP). The repository provides a comprehensive collection of administrative, registry, survey, and other types of data on all Manitoba residents through a universal and publicly funded health system (Supplementary Table 1). All records in the repository are de-identified, and linkage among different databases was achieved through encrypted Personal Health Identification Numbers (PHIN).

The study included a cohort of children aged 1 to 5 years living in Manitoba between January 1, 2004, and December 31, 2015. For each calendar year, children were followed from the earlier of their first birthday, if it occurred during the calendar year, or the start of the year (January 01) until the earliest of ASD diagnosis, migration out of province, age of 5 years, death, or end of the calendar year (December 31). The study was approved by the University of Manitoba Health Research Ethics Board and the Health Information Privacy Committee of Manitoba Health, Seniors and Active Living.

Case ascertainment

The International Classification of Disease (ICD) coding system in the 9th and 10th revisions was used to identify ASD cases from hospital abstract claims and physician claims of the medical services database. An established and validated ASD identification algorithm with a positive predictive value of 88% was used to identify ASD diagnosis (Brownell et al.

Table 1 Annual ASD prevalence and incidence: overall and stratified

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of prevalent ASD cases	229	239	263	249	290	287	291	316	384	477	514	578
Average population	50,327	49,993	49,858	50,275	51,397	53,131	55,068	56,668	57,518	58,104	58,765	59,438
Prevalence (%)	0.46	0.48	0.53	0.50	0.56	0.54	0.53	0.56	0.67	0.82	0.87	0.97
Standardized prevalence (%)	0.45	0.47	0.52	0.49	0.56	0.54	0.53	0.56	0.67	0.82	0.87	0.97
Sex												
Boys	0.71	0.72	0.80	0.74	0.87	0.86	0.85	0.87	1.01	1.25	1.35	1.52
Girls	0.18	0.23	0.24	0.24	0.25	0.20	0.20	0.23	0.32	0.38	0.37	0.39
Region												
Rural	0.28	0.31	0.37	0.31	0.33	0.33	0.34	0.40	0.45	0.55	0.55	0.58
Urban	0.59	0.61	0.65	0.64	0.75	0.71	0.68	0.69	0.85	1.05	1.15	1.30
SES												
High	0.46	0.48	0.53	0.58	0.62	0.53	0.51	0.50	0.57	0.77	0.84	0.85
Middle	0.59	0.51	0.54	0.50	0.60	0.61	0.57	0.55	0.67	0.81	0.78	0.85
Low-mid	0.48	0.57	0.61	0.51	0.63	0.58	0.56	0.59	0.70	0.89	0.97	1.10
Low	0.22	0.30	0.40	0.43	0.40	0.38	0.42	0.56	0.66	0.76	0.91	1.05
Number of incident ASD cases	80	100	104	91	126	110	101	144	157	223	217	232
Person-years	50,155	49,612	49,490	49,896	51,263	52,763	54,741	56,348	57,323	57,710	58,352	58,870
Incidence rate (%)	0.16	0.20	0.21	0.18	0.25	0.21	0.18	0.26	0.27	0.39	0.37	0.39
Standardized incidence (%)	0.16	0.20	0.21	0.18	0.25	0.21	0.19	0.26	0.28	0.39	0.37	0.39
Sex												
Boys	0.25	0.30	0.33	0.27	0.37	0.35	0.29	0.39	0.40	0.62	0.60	0.63
Girls	0.06	0.09	0.08	0.09	0.12	0.06	0.07	0.12	0.14	0.14	0.14	0.14
Region												
Rural	0.09	0.14	0.16	0.10	0.13	0.15	0.12	0.19	0.19	0.26	0.22	0.24
Urban	0.22	0.25	0.25	0.24	0.34	0.26	0.23	0.31	0.34	0.49	0.50	0.52
SES												
High	0.18	0.16	0.19	0.21	0.23	0.14	0.18	0.21	0.23	0.38	0.39	0.21
Middle	0.19	0.21	0.21	0.17	0.29	0.22	0.20	0.22	0.30	0.36	0.34	0.38
Low-mid	0.17	0.23	0.22	0.19	0.29	0.25	0.19	0.29	0.24	0.44	0.37	0.45
Low	0.09	0.16	0.21	0.18	0.12	0.17	0.16	0.28	0.30	0.35	0.43	0.40

2008; Vehling et al. 2016; Dodds et al. 2009; Boukhris et al. 2016). ASD was defined as having one or more hospitalizations with an ASD code (ICD-9299.0, 299.1, 299.8 or 299.9, or ICD-10 F84.0, F84.1, F84.3, F84.5, F84.8, or F84.9) or one or more physician visits with ICD-9 code of 299.

The ASD prevalence numerator was defined as the number of subjects aged 1 to 5 years with ASD diagnosis during the calendar year; the prevalence denominator was the average number of subjects aged 1 to 5 years living in Manitoba in each calendar year. The ASD incidence numerator was defined as the number of new ASD cases identified in each calendar year among subjects aged 1 to 5 years; the incidence denominator comprised the total person-years contributed by subjects aged 1 to 5 years who are at risk for ASD during the calendar year. For incident ASD cases, hospitalization and physician visit records were reviewed from date of birth to ensure no prior ASD diagnoses.

Statistical analysis

Descriptive analyses were first conducted to report overall annual prevalence and incidence, which were then adjusted according to sex and region using direct standardization by the average population composition throughout study years. Additionally, annual prevalence and incidence were stratified according to sex, region (rural vs urban), and socio-economic status (SES). SES was measured using the Socio-economic Factor Index (SEFI), an area-level measure derived from census data. SEFI was categorized with cutoff points within one standard deviation from the mean into high, middle, low middle, and low SES.

To examine changes in prevalence and incidence over study years using the year 2004 as a reference category, a multi-variable negative binomial regression, a generalization of Poisson model allowing for overdispersion, was used after

Fig. 1 Time trends in ASD prevalence: by sex (a) and by region (b)

adjusting for sex, region, and SES. The statistical software SAS® 9.4 (SAS Institute; Cary, NC, USA) was used for all data analyses.

Results

In the year 2004, 50,327 children between the ages of 1 and 5 years were living in Manitoba. This population increased to 59,438 in 2015. Among children aged 1 to 5 years, 1685 ASD cases were diagnosed between 2004 and 2015 at a mean age of 3.3 years with a standard deviation (SD) of 0.96. Between 2004 and 2015, an overall prevalence of 0.63% and an overall incidence of 0.26% were estimated for the study population.

The crude ASD prevalence increased by over twofold (111%) from 0.46% in 2004 to 0.97% in 2015 ($p = 0.002$). The annual prevalence remained unchanged after adjusting for sex and region by direct standardization (Table 1). Between 2004 and 2015, annual prevalence increased by 2.14-fold in boys, 2.17-fold in girls (Fig. 1a), 2.07-fold for those residing in a rural area and 2.20-fold for those residing in an urban area (Fig. 1b). Among SES groups, the highest increase

in ASD prevalence was observed in the low SES group with 4.77-fold increase between 2004 and 2015 (Table 1). In all study years, ASD prevalence was higher in boys than girls, with a mean ratio of 3.6 (SD 0.43). Similarly, prevalence was higher for those residing in an urban area compared with those in a rural area, with a mean ratio of 2.0 (SD 0.17).

The crude incidence rate increased by over twofold (144%) from 0.16% in 2004 to 0.39% in 2015 ($p = 0.002$). The annual incidence remained unchanged after adjusting for sex and region by direct standardization (Table 1). Between 2004 and 2015, annual incidence increased by 2.52-fold in boys, 2.33-fold in girls (Fig. 2a), 2.67-fold for those residing in a rural area and 2.36-fold for those residing in an urban area (Fig. 2b). Among SES groups, the highest increase in ASD incidence was observed in the lowest SES group with 4.44-fold increase between 2004 and 2015 (Table 1). In all study years, ASD incidence was higher for boys than girls, with a mean ratio of 3.9 (SD 0.85). Similarly, incidence was higher for those residing in an urban area compared with those in a rural area, with a mean ratio of 2.0 (SD 0.35).

The negative binomial model adjusted for sex, region, and SES showed an annual relative risk increase, since 2004, for

Fig. 2 Time trends in ASD incidence rate: by sex (a) and by region (b)

both prevalence and incidence of 1.69 (95% CI 1.56–1.83, $p < 0.0001$) and 1.84 (95% CI 1.62–2.09, $p < 0.0001$), respectively. ASD prevalence in 2015 was 2.17 times higher than the prevalence in the year 2004 (95% CI 1.84–2.57) (Table 2). Similarly, ASD incidence rate in 2015 was 2.48 times higher than the incidence in 2004 (95% CI 1.88–3.28) (Table 3). ASD prevalence and incidence appear to be associated with sex and region. In the adjusted model, the prevalence was 3.59 times (95% CI 3.31–3.89) and incidence was 3.86 times (95% CI 3.39–4.40) higher in boys compared with girls (Tables 2 and 3). For children residing in urban area, the prevalence was 2.05 times (95% CI 1.90–2.21) and incidence was 2.02 times (95% CI 1.80–2.27) higher compared with those residing in rural area (Tables 2 and 3). Compared with children in the highest SES group, those in the lowest group had 1.18 times (95% CI 1.03–1.33) higher prevalence and 1.37 times (95% CI 1.11–1.72) higher incidence of ASD.

Discussion

In this large population-based study consisting of all children aged 1 to 5 years residing in Manitoba between 2004 and

2015, we found a significant linear increase in ASD prevalence and incidence over the study period. The crude prevalence and incidence of ASD increased by 3.11-fold and 3.44-fold, respectively, between 2004 and 2015. These increases remained significant after adjusting for sex, region, and SES. Prevalence and incidence increases were observed in both sexes, regions, and in all SES groups, and was most profound in the low SES group. ASD prevalence and incidence were higher in boys compared with girls, in those residing in an urban area compared with those in a rural area, and in those within the lowest SES group compared with those in the highest group.

The increase in ASD prevalence is consistent with previous literature. In the US, the prevalence increased by 2.18 times between 2000 and 2012 (Christensen 2012; CDC 2018). Similarly, in Manitoba, the prevalence increased by 2.55 times between 2000 and 2014 (Brownell et al. 2008; Vehling et al. 2016). Unlike prevalence, data on changes of ASD incidence are scarce. A population-based cohort study of children aged 0 to 4 years residing in Hong Kong reported a stable incidence rate of ASD of about 5 cases per 10,000 person-years, between 1986 and 2000. This estimate increased to about 8 cases per 10,000 person-years between 2001 and 2005 (Wong and Hui

Table 2 Relative risk of ASD prevalence: crude and adjusted

Variable	Crude relative risk (95% CI)	<i>P</i> value	Adjusted* relative risk (95% CI)	<i>P</i> value
Calendar year				
2004	1.00		1.00	
2005	1.08 (0.64–1.85)	0.766	1.06 (0.87–1.29)	0.542
2006	1.18 (0.69–2.00)	0.551	1.18 (0.97–1.43)	0.092
2007	1.12 (0.66–1.91)	0.675	1.11 (0.91–1.35)	0.288
2008	1.26 (0.74–2.15)	0.391	1.26 (1.04–1.51)	0.017
2009	1.21 (0.71–2.06)	0.480	1.21 (1.00–1.45)	0.051
2010	1.21 (0.71–2.06)	0.477	1.19 (0.99–1.43)	0.071
2011	1.28 (0.75–2.17)	0.363	1.26 (1.05–1.52)	0.013
2012	1.55 (0.92–2.62)	0.102	1.52 (1.27–1.82)	< 0.0001
2013	1.91 (1.13–3.22)	0.015	1.86 (1.57–2.22)	< 0.0001
2014	2.06 (1.22–3.46)	0.007	1.98 (1.66–2.35)	< 0.0001
2015	2.31 (1.37–3.88)	0.002	2.17 (1.84–2.57)	< 0.0001
Sex				
Girls	1.00		1.00	
Boys	3.48 (2.98–4.07)	< 0.0001	3.59 (3.31–3.89)	< 0.0001
Region				
Rural	1.00		1.00	
Urban	2.03 (1.65–2.48)	< 0.0001	2.05 (1.90–2.21)	< 0.0001
SES				
Low	1.00		1.00	
Low-mid	1.08 (0.78–1.49)	0.652	1.10 (1.00–1.21)	0.057
Middle	1.00 (0.72–1.38)	0.996	1.01 (0.92–1.11)	0.831
High	0.90 (0.64–1.27)	0.543	0.85 (0.75–0.97)	0.018

Italicized *p*-values indicate statistical significance at the 0.05 level

*Adjusted for sex, region, and SES

Table 3 Relative risk of ASD incidence: crude and adjusted

Variable	Crude relative risk (95% CI)	<i>P</i> value	Adjusted* relative risk (95% CI)	<i>P</i> value
Calendar year				
2004	1.00		1.00	
2005	1.27 (0.70–2.30)	0.438	1.27 (0.92–1.75)	0.147
2006	1.29 (0.71–2.34)	0.404	1.32 (0.96–1.82)	0.083
2007	1.17 (0.64–2.14)	0.609	1.15 (0.83–1.60)	0.393
2008	1.49 (0.83–2.70)	0.185	1.56 (1.15–2.11)	<i>0.005</i>
2009	1.33 (0.73–2.40)	0.349	1.33 (0.97–1.82)	0.077
2010	1.18 (0.65–2.14)	0.595	1.18 (0.86–1.62)	0.317
2011	1.60 (0.90–2.88)	0.114	1.63 (1.21–2.20)	<i>0.001</i>
2012	1.81 (1.01–3.25)	<i>0.046</i>	1.75 (1.30–2.36)	<i>0.0002</i>
2013	2.50 (1.41–4.45)	<i>0.002</i>	2.46 (1.86–3.25)	<i>< 0.0001</i>
2014	2.44 (1.37–4.34)	<i>0.002</i>	2.35 (1.78–3.12)	<i>< 0.0001</i>
2015	2.49 (1.40–4.43)	<i>0.002</i>	2.48 (1.88–3.28)	<i>< 0.0001</i>
Sex				
Girls	1.00		1.00	
Boys	3.80 (3.14–4.60)	<i>< 0.0001</i>	3.86 (3.39–4.40)	<i>< 0.0001</i>
Region				
Rural	1.00		1.00	
Urban	1.93 (1.52–2.45)	<i>< 0.0001</i>	2.02 (1.80–2.27)	<i>< 0.0001</i>
SES				
Low	1.00		1.00	
Low-mid	1.02 (0.71–1.46)	0.926	1.02 (0.88–1.18)	0.808
Middle	0.95 (0.66–1.36)	0.777	0.93 (0.80–1.08)	0.353
High	0.83 (0.55–1.23)	0.345	0.73 (0.58–0.90)	<i>0.004</i>

Italicized *p*-values indicate statistical significance at the 0.05 level

*Adjusted for sex, region, and SES

2008). While genetics are important determinants in the development of ASD, they are not exclusive contributors and they do not explain the increase in ASD incidence (Geschwind 2011; Hallmayer 2011; Gardener et al. 2009, 2011). This triggered an extensive amount of research to investigate the role of environmental factors. Several prenatal and postnatal exposures were reported as predictors of ASD, such as maternal psychiatric conditions, premature birth, birth complications, and prenatal exposure to antidepressants (Gardener et al. 2009; Gardener et al. 2011; Duan et al. 2014; Mezzacappa et al. 2017). However, because of the potential of confounding, a causal relationship remains inconclusive.

The increase in ASD prevalence can also be attributed to other factors (Wing and Potter 2002; Elsabbagh et al. 2012). Increased funding and research evidence on the disorder may have resulted in increased public and healthcare providers' awareness and, accordingly, increased identification. In addition, current recommendations of earlier ASD diagnosis may have affected prevalence by increasing the number of cases identified at younger ages. Changes in ASD diagnostic criteria to a broader definition may have resulted in more cases being identified. Moreover, ASD prevalence increase reported in

previous studies may have been attributed to utilizing different methodologies. In this study, we identified ASD cases by applying similar identification algorithm and diagnostic codes throughout study years. In addition, we limited the cohort to children aged 1 to 5 years to eliminate the effect of a delayed identification of cases in adolescence and adulthood.

The higher prevalence of ASD in boys is consistent with previous studies (Reinhardt et al. 2015; Yeargin-Allsopp et al. 2003; Werling and Geschwind 2013). Although the exact mechanism for this sex bias is still unknown, several potential mechanisms have been proposed. The first mechanism is the difference in clinical phenotype, where symptoms of aggressive and repetitive behaviour are more commonly reported in boys with ASD (Hattier et al. 2011; Mandy et al. 2012). In contrast, girls with ASD present more commonly with internalizing symptoms, including depression and anxiety (Solomon et al. 2012), which are harder to identify. Other mechanisms that have been suggested involve the male sex hormone testosterone and sex chromosomal genes as contributors in the development of ASD (Werling and Geschwind 2013; Auyeung et al. 2009). The higher prevalence of ASD in children residing in an urban area is also consistent with previous studies

(Rosenberg et al. 2009; Lauritsen et al. 2014; Hoshino et al. 1982; Lauritsen et al. 2005). This can be attributed to difficulties in healthcare access in rural areas, including unavailability of specialists, geographic distance to service providers, and referrals to specialists and centres in urban areas.

The current study has several strengths. First, we utilized population-based data with a large sample size. Second, using claims data from Manitoba where the health system is universal and publicly funded reduces the inequities in access to health services and provides a relatively homogenous population representation. Third, applying similar case identification algorithm allowed for a more consistent comparison across study years. Nevertheless, it is important to acknowledge the few limitations that we identified. First, while the utilized ASD identification algorithm was validated, misclassification of ASD diagnosis remains a potential limitation. However, since we are using the same algorithm throughout the study period, the risk ratio of ASD prevalence and incidence between study years remains valid. In addition, we estimated the prevalence and incidence of physician-diagnosed ASD cases, but we were not able to capture cases diagnosed by other healthcare providers (e.g., psychologists) or undiagnosed cases. As such, we are reporting the prevalence and incidence of physician-diagnosed ASD cases and not necessarily true ASD prevalence and incidence. Since privately funded services such as psychologist visits are not captured in the repository, this might have resulted in underreporting in children in the highest SES group who can afford these services and in those living in urban areas who have better accessibility. Second, we could not account for the increased ASD cases identification due to increased public and healthcare providers' awareness and due to ASD diagnosis at a younger age in recent years, which could be an alternative explanation of the increase in ASD incidence. We also could not eliminate the effects of changes in diagnostic criteria on prevalence and incidence rates. Finally, the cohort included subjects who were born in Manitoba; thus, results are not generalizable to children who immigrated to Manitoba after birth from other provinces or other countries.

Conclusion

Study findings suggest a significant increase in diagnosed ASD prevalence and incidence in children aged 1 to 5 years residing in Manitoba between 2004 and 2015. However, we cannot exclude the effects of changes in diagnostic criteria, improved identification, and earlier diagnosis as contributing factors to this increase. The increase in ASD cases should be considered when allocating health and other support services. Future studies with appropriate confounding control are needed to examine environmental factors involved in ASD development.

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Compliance with ethical standards

Ethical approval The study was approved by the University of Manitoba Health Research Ethics Board and the Health Information Privacy Committee of Manitoba Health, Seniors and Active Living.

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