Original research

Incidence and prevalence of paediatric-onset multiple sclerosis in two Canadian provinces: a population-based study representing over half of Canada’s population

Fardowsa L Yusuf,1,2 Ayesha Asaf,3 Ruth Ann Marrie,4 Ping Li,3 Kyla McKay,5 Yinshan Zhao,1 Feng Zhu,1 Colleen Maxwell,3,6 Helen Tremlett1

ABSTRACT

Background Population-based studies estimating the epidemiology of paediatric-onset multiple sclerosis (PoMS) are scarce.

Methods We accessed population-based health administrative data from two provinces in Canada, Ontario and British Columbia (BC). Individuals with PoMS were identified via a validated case definition. The index date (‘MS onset’) was the first demyelinating or MS specific claim recorded ≤18 years of age. We estimated the age-standardised annual incidence and prevalence of PoMS, and 95% CIs between 2003 and 2019. We used negative binomial regression models to assess the temporal changes in the annual crude incidence and prevalence of PoMS, and the ratios comparing sex groups.

Results From 2003 to 2019, a total of 148 incident PoMS cases were identified in BC, and 672 in Ontario. The age-standardised annual incidence of PoMS was stable in both provinces, averaging 0.95 (95% CI 0.79 to 1.13) in BC and 0.98 (95% CI 0.84 to 1.12) in Ontario per 100,000 person-years. The incidence ratio by sex (female vs male) was also stable over the study period, averaging 1.5:1 (95% CI 1.06 to 2.08, BC) and 2.0:1 (95% CI 1.61 to 2.59, Ontario). The age-standardised prevalence per 100,000 people rose from 4.75 (2003) to 5.52 (2019) in BC and from 2.93 (2003) to 4.07 (2019) in Ontario, and the increase was statistically significant in Ontario (p=0.002). There were more female prevalent PoMS cases than males in both provinces.

Conclusions Canada has one of the highest rates of PoMS globally, and the prevalence, but not incidence, has increased over time. Allocation of resources to support the growing youth population with MS should be a priority.

INTRODUCTION

Multiple sclerosis (MS) is a chronic, inflammatory disease of the central nervous system (CNS), with symptom onset typically occurring between the ages of 20 and 50 years. However, an estimated 2%-10% of people with MS experience their first symptoms in childhood or adolescence.1 MS is considered as one disease across the age span; individuals with paediatric (PoMS) and adult-onset MS share the same risk factors for onset.2

Paediatric-onset MS (PoMS) is, however, associated with a more inflammatory disease course, including having a higher relapse rate after disease onset1 and a greater MRI burden at clinical presentation.1 Individuals with PoMS also reach key disability milestones (as measured by the Expanded Disability Status Scale), at a younger age than their adult-onset counterparts.2

Few population-based epidemiological studies have described the incidence and prevalence of the PoMS population. This knowledge gap creates barriers to research and resource allocation. Health administrative (claims) data in a universal healthcare setting offer the opportunity to access health-related information on virtually all residents, including Canadian citizens, permanent...
residents and refugees. One study, based in the province of Ontario, Canada, successfully validated PoMS case definitions using such data, and found Ontario to have among the highest rates of PoMS recorded, globally. While important, authors were only able to include data through until 2014 and from one region. More recent estimates of the occurrence of PoMS are needed, and ideally across more than one region using similar research methods. Identifying comparable regional differences, including in sex and age, may provide insights into the environmental drivers of PoMS. Monitoring the incidence of PoMS allows for the identification of temporal changes in the awareness, diagnosis and risk factors of PoMS. Determining the prevalence of PoMS assists with the planning of health services and social care for children and adolescents with MS as they age, and appropriate supports for family caregivers.

Therefore, we estimated the incidence and prevalence of PoMS in two distinct regions (British Columbia (BC) and Ontario) in Canada which, combined, represent over 50% of the nation’s population. We also estimated and compared the incidence and prevalence sex and age ratios of PoMS and examined temporal changes from 2003 to 2019.

METHODS

Data access and setting

We conducted population-based retrospective cohort studies in two Canadian provinces (Ontario and BC). BC has no published data on PoMS, and Ontario lacks information from 2014 onwards (through until 2019, Ontario’s population grew by over 1 million persons). These provinces also represent two geographically diverse areas: BC is on the west coast and Ontario is located in eastern-central Canada. In 2019, an estimated 1 million children and adolescents aged ≤18 years lived in BC, and 3 million in Ontario. As of 2021, BC and Ontario have comparable proportions of their populations living in rural areas (12.7% and 13.3%, respectively). Both provinces have universal, publicly funded healthcare systems that provide medically necessary hospital and physician services.

Study cohorts and data sources

We accessed multiple health administrative databases that were linked deterministically for each person based on their unique healthcare number. All linkages and analyses were performed separately within each province using a common analytical plan, in accordance with the data access and privacy agreements. In Ontario, the databases were linked using encoded identifiers and analysed at ICES (formerly the Institute for Clinical Evaluative Sciences’), an independent, non-profit research institute whose legal status under Ontario’s health information privacy law allows it to collect and analyse healthcare and demographic data, without consent, for health system evaluation and improvement. BC’s data access and linkages are similar; Population Data BC is the electronic repository of administrative health records and analysis was conducted within the virtual, secure research environment (SRE) provided. Only the aggregated results were permitted to report in each province.

The health administrative data accessed for this study are described further in online supplemental table 1 and summarised here. The health insurance registries provided each person’s year and month of birth, sex, residential postal code and dates registered in the provincial health insurance system. Rural (vs urban) residence was determined from the residential postal codes. Neighbourhood-level income quintiles were based on each province’s census data. The physician claims databases (Ontario Health Insurance Plan, BC’s Medical Services Plan) provided the dates of health service use (eg, an office visit to a physician, including general practitioners and specialties such as ophthalmologists and neurologists, and to other health professionals covered by the provincial insurance programme, including optometrists) and the physician-assigned International Classification of Disease (ICD)-9 codes. The Discharge Abstract Database provided the admission and discharge dates of hospital stays, including same-day stays, and up to 25 ICD-10-Canadian modification (CA) codes recorded at discharge (up to 16 ICD-9 codes were available before 1 April 2001), alongside province-specific codes. Deaths were recorded in Vital Statistics Data and registration data. Following data linkage, we accessed all these data from 1998 to 2019.

Selection of PoMS cases

To identify individuals with PoMS, we applied a previously validated algorithm (positive predictive value=100%, negative predictive value=91.5%). PoMS cases were required to have ≥3 MS-specific hospital or physician claims on separate days, with the earliest demyelinating/MS-specific claim (‘MS onset’) occurring ≤age 18 years (online supplemental table 2). The date of the first demyelinating/MS specific claim constituted the index date.

Incidence and prevalence

Incident PoMS cases were identified as those with an index date in the calendar year of interest and no prior demyelinating/MS disease claims in the preceding 5 years. Thus, the earliest possible index date was 1 January 2003, to allow a full 5 years of no such disease claims. To ensure each PoMS case had sufficient data to accurately classify them as an incident or prevalent case, individuals had to be registered in the health insurance system for at least 90% of the days in each of the 5 years before the index date. Registration in the health system is mandatory for all residents in each province, thus this serves as a proxy to ensure a person was resident in the province at the time of our study. Beyond registration, a person did not need to actively engage in (or use) the health system to be included. Children <5 years at the index date had to meet the same requirements, but from birth. PoMS cases were considered prevalent from the index date until the earliest of their 18th year of life, death or emigration from the province.

Analyses

We estimated the crude annual incidence and point prevalence (determined on 1 July) of PoMS from 2003 to 2019 and calculated the 95% CIs using the Poisson and exact binomial distributions, respectively. We determined the incidence and prevalence estimates stratified by sex and age (<12, 12–15, 16–18 years), and the corresponding rate ratios (RR). Age group selection was guided by the literature and ensured an adequate number of cases per group to meet reporting requirements for privacy/confidentiality. To compare our estimates to those reported in other regions, we age-standardised using the world standard population (2000–2025),

The demographic characteristics of all incident MS cases in the study period (2003–2019) were summarised, including sex, age, neighbourhood income level (quintiles) and region of residence (urban or rural). The prevalent PoMS cases (ie, people with MS aged 18 or younger who were residents of the province) were similarly described on 1 July 2019. We modelled the temporal changes in the annual incidence and prevalence by incorporating


230
calendar year as a continuous independent variable in negative binomial regression models, and adjusted for sex and age (<12, 12–15, 16–18 years) at the index date. For incidence, the model offset was the total person-time at risk for PoMS among children and youth aged 18 years and younger. For prevalence, the offset was the entire population of people aged 18 years and younger. The offsets were derived from provincial population estimates.12 18 We introduced interaction terms between calendar year and sex, and between calendar year and age, to evaluate trends in the incidence and prevalence sex and age ratios of the PoMS population. RR and 95% CIs were reported. Analyses were conducted using SAS (V.9.4) and R (V.4.0.5).

Data
Administrative data access was provided by ICES and Population Data BC. Ontario’s data were held securely in coded form at Population Data BC’s SRE. Data sharing agreements prohibit making these datasets publicly available. However, access may be granted; details available at ices.on.ca/DAS and https://www.popdata.bc.ca/data_access.

RESULTS
Between 2003 and 2019, we identified 820 incident PoMS cases (148 in BC and 672 in Ontario). On 1 July 2019, there were 177 prevalent PoMS cases (51 in BC and 126 in Ontario) (table 1). Females accounted for a somewhat higher proportion of the PoMS cases in Ontario (66% in the incident cohort and 68% in the 2019 prevalent cohort) as compared with BC (58% in the incident cohort and 49% in the 2019 prevalent cohort). At the index date, the average age of the incident PoMS cases was 14–15 years across both provinces. On average, the prevalent PoMS cases in 2019 were younger at index date; 9 years in BC and 11 years in Ontario. Most PoMS cases (>90%) lived in urban locations (consistent with the general population).10 A greater proportion of the prevalent PoMS cases in Ontario lived in neighbourhoods with higher incomes, compared with the province’s general population. Incident PoMS cases in BC were less likely to live in the least and most affluent neighbourhoods (income quintiles), while incident PoMS cases in Ontario were less likely to live in the lower income neighbourhoods, as compared with each province’s general population. The average difference between the index date and the first MS-specific claim was 11 months in BC, and 4 months in Ontario.

Incidence of PoMS
Between 2003 and 2019, the age-standardised annual incidence rates of PoMS per 100 000 person-years were similar between the provinces, averaging 0.95 (95% CI 0.79 to 1.13) in BC and 0.98 (95% CI 0.84 to 1.12) in Ontario. The incidence rates remained relatively stable in both provinces, with no significant temporal changes observed (figure 1; from model, BC: RRyear=1.02, 95% CI 0.98 to 1.05, p=0.40; Ontario: RRyear=1.00, 95% CI 0.96 to 1.02, p=0.42). Females had a higher incidence than males in both provinces (from model, adjusted for calendar year, BC: RRsex=2.05, 95% CI 1.61 to 2.59, p<0.0001), and this difference was somewhat higher in Ontario, though the CIs overlapped. No temporal changes were observed in the female:male incidence ratio in either province (from model, BC: Pinteraction=0.22; Ontario: Pinteraction=0.43). Findings are illustrated in figure 2 for Ontario (given its larger population size). The incidence of PoMS increased with age in both provinces (from model, BC: p<0.0001; Ontario: p<0.0001). In BC, 12–15 years had on

### Table 1 Characteristics of the incident and prevalent PoMS cases in British Columbia and Ontario, Canada

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>British Columbia</th>
<th>Ontario</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>148</td>
<td>51</td>
</tr>
<tr>
<td>Female, N (%)</td>
<td>86</td>
<td>25</td>
</tr>
<tr>
<td>Age at 1 July, mean (SD)</td>
<td>13.1 (4.40)</td>
<td>8.9 (5.45)</td>
</tr>
<tr>
<td>Age at index date, years, mean (SD)</td>
<td>14.1 (4.57)</td>
<td>15.0 (4.91)</td>
</tr>
<tr>
<td>Female, N (%)</td>
<td>86</td>
<td>25</td>
</tr>
<tr>
<td>Age at index date, category, years, N (%)</td>
<td>&lt;12 30 (20.3)</td>
<td>15.6 (5.08)</td>
</tr>
<tr>
<td>Age at first MS-specific code, years, mean (SD)</td>
<td>16–18 83 (56.1)</td>
<td>6.6 (11.8)</td>
</tr>
<tr>
<td>Age at third MS-specific code, mean (SD)</td>
<td>16–18 83 (56.1)</td>
<td>6.6 (11.8)</td>
</tr>
<tr>
<td>Income quintile, N (%)</td>
<td>1 (least affluent) &lt;10†</td>
<td>129 (19.2)</td>
</tr>
<tr>
<td>Rural Urban</td>
<td>135 (91.2)</td>
<td>51†</td>
</tr>
<tr>
<td>Region of residence, N (%)</td>
<td>13 (8.8)</td>
<td>51†</td>
</tr>
</tbody>
</table>
| *Prevalent PoMS cases were children and youth with MS aged 18 or younger in the year of interest that reside in the province.  
†In accordance with the data access and privacy requirements, results are not reported when a small number of cases (<6) occurred in a subgroup. Given that these small subgroups could be back-calculated from the total, we also suppressed the second smallest cell size of the corresponding variables.  
MS, multiple sclerosis; n, sample size; PoMS, paediatric-onset MS.
average 3.15 (95% CI 1.93 to 5.15) times the incidence of children aged <12 years, and 16–18 years had 9.09 (95% CI 6.06 to 14.02) times the incidence. A similar pattern was found in Ontario where the respective rate ratios were 4.5 (95% CI 3.22 to 6.17) and 14.5 (95% CI 10.7 to 19.6). In both provinces, there were no significant changes over time in the age-specific incidence ratios (from model, BC: p_interaction=0.94, 0.79; Ontario: p_interaction=0.41, 0.23).

Prevalence of PoMS
The age-standardised prevalence of PoMS rose in both provinces during the study period. An increase from 4.75 (95% CI 3.44 to 6.40) to 5.52 (95% CI 4.11 to 7.27) per 100 000 persons was observed in BC, and from 2.93 (95% CI 2.45 to 3.47) to 4.07 (95% CI 3.39 to 4.85) in Ontario, reaching significance in Ontario only (figure 3; from model, BC: RR year 1.01, 95% CI 0.996 to 1.02, p=0.17; Ontario: RR year 1.02, 95% CI 1.01 to 1.03, p=0.002). The prevalence was higher in females than males (figure 4); the average prevalence sex ratio was 1.19 (from model, 95% CI 1.03 to 1.37, p=0.02) in BC, and 1.72 (95% CI 1.54 to 1.91, p<0.0001) in Ontario. The sex ratio significantly increased over the study period in Ontario, with the largest increases observed between 2007 and 2011 (from model, p_interaction<0.0001). A decrease in the sex ratio was observed for BC, but numbers were not large enough to stabilise the estimates (figure 4; from model, p_interaction<0.0001). The prevalence of PoMS rose with age, reaching significance in Ontario (from model, p<0.0001). Compared with children aged <12 years in Ontario, 12–15 years had 3.72 (95% CI 3.27 to 4.23) times the prevalence and 16–18 years had 8.91 (95% CI 7.92 to 10.03) times the prevalence over the study period. These age ratios increased with time in Ontario (from model, p_interaction=0.007, 0.004).

DISCUSSION
In this population-based study, we used a validated algorithm to determine the incidence and prevalence of PoMS over a 16-year period in two Canadian provinces (approximately 4 million children and youth in 2019). Based on these two regions, our findings show that Canada has some of the highest prevalence estimates of PoMS in the world (5.52 per 100 000 people in BC, and 4.07 per 100 000 people in Ontario). Between 2003 and 2019, the incidence of PoMS was stable in the two regions, with an average of 0.95 per 100 000 person-years in BC and 0.98 per 100 000 person-years in Ontario. The incidence and prevalence of PoMS were higher in females than males, and increased with...
The prevalence of PoMS increased over the study period in the two provinces, reaching statistical significance in one region (Ontario). Our findings provide much-needed insights into the incidence and prevalence of PoMS and facilitate resource allocation and health services planning which should include a priority to support the growing population of children and youth with MS.

Our PoMS incidence estimates exceed those of most prior studies (online supplemental table 3). A US population-based study accessed electronic databases in Southern California and estimated the incidence of PoMS to be 0.5 per 100,000 person-years among children aged ≤18 years between 2004 and 2009. In Germany, the nationwide incidence of PoMS (onset ≤15 years of age) was estimated to be 0.64 per 100,000 person-years from 2009 to 2011 based on an active surveillance system involving all MS centres. During 1977–2015, a study using the Danish MS Registry estimated the incidence of PoMS among children younger than 18 years to be 0.79 per 100,000 person years. In the Netherlands, children with onset of acquired demyelinating syndromes before age 18 years were identified from 2007 to 2010 using two sources (the Dutch paediatric MS study group and the Dutch surveillance of rare paediatric disorders). From these, the annual incidence of PoMS was estimated to be 0.15 per 100,000 children. In an MS registry-based study in the city of Saskatoon, Canada, which obtained information from a number of sources, including medical records from physicians and neurologists, the incidence of MS among children aged 14 years or less between 1970 and 2004 was 0.15 per 100,000 population. Although the rate increased to 11.5 per 100,000 population in 15–24 years, no results specific to those 18 years or under were reported. A retrospective survey based on medical records from 1990 to 2009 in Iceland estimated the incidence of PoMS as 0.45 per 100,000 population.

However, a few small studies have reported higher PoMS incidence rates (online supplemental table 3). In Kuwait, researchers accessed a national MS registry and found that per 100,000 children aged <18 years in 2013, the incidence of PoMS was 2.1. A cohort study in northern Sardinia, Italy enrolled children with PoMS aged 18 years and less from 2001 to 2012, and reported an annual average incidence of 2.85 per 100,000 population. These two studies were also among the few studies that estimated the prevalence of PoMS. The prevalence per 100,000 was estimated to be 6.0 per 100,000 children in Kuwait, and 26.92 per 100,000 in Sardinia. The incidence estimates in Kuwait and Sardinia are substantially higher than our own, as is the prevalence estimate in Sardinia. However, these estimates were based on very low patient numbers; only 11 PoMS cases were identified in 2013 in Kuwait, and Sardinia’s population is special, having a particularly high genetic burden for MS due to the island’s ‘founder effect’, therefore, comparability is limited.

One study in Japan that surveyed 977 hospitals between 2008 and 2009 reported a prevalence that was lower than our own of 0.69 per 100,000 children. It is possible that the population-based data sources used in our study provide more accurate estimates than methods employed in other regions. The geographical variation in PoMS incidence concurs with the Global Burden of Disease Study which concluded that Canada had one of the highest incidence rates of MS, irrespective of age, worldwide (1990–2016). This study, however, included all persons with MS and did not report findings in the PoMS populations. Further, our study employed a PoMS definition which included persons who were 18 years of age, which likely contributed to our higher estimates, relative to the published literature.

Despite increased awareness of PoMS over the study period, the incidence of PoMS was stable in both Canadian regions. However, the prevalence of PoMS increased, likely due to the earlier diagnosis of children with MS leading to longer disease durations. Increased immigration of children at greater risk of developing MS may also increase the prevalence of PoMS. Evidence suggests that MS is a single disease across the life span, and with the adult MS population of Canada also exhibiting stable incidence and increased prevalence of MS over time. However, potential underdiagnosis in the paediatric population due to lower awareness of PoMS among healthcare providers limits comparisons. As with previous studies, we found a higher incidence and prevalence for females in Ontario. Our sex-stratified incidence and prevalence estimates from BC were less stable and harder to interpret. A single study analysed differences in age groups and similarly found an increased incidence with age. Consistent with these observations, the average age at PoMS onset was reported as 15–16 years in Denmark and Kuwait, indicating a greater distribution of PoMS cases in the adolescent population.

Major strengths of this study included the application of a validated algorithm using population-based data to ascertain PoMS cases, the use of a common protocol across provinces, a study period spanning 17 years that extended to 2019, and the inclusion of 50% of Canadian youth across two geographically distinct provinces. Several limitations are worth noting. To describe the cohort, we were restricted to the demographic variables available in the health administrative databases (eg, age, sex and area-level socioeconomic status). Although we applied a validated algorithm, the misclassification of PoMS cases was still possible. We anticipate that this misclassification would lead to an underestimation of the true PoMS incidence and prevalence. We were unable to apply the same registration requirements to the general population, which may have led to larger offsets and lower incidence and prevalence estimates. It is also possible that despite imposing a 5-year run in period, this may not be sufficient to identify incident PoMS cases. However, in the paediatric population, the second demyelinating event typically occurs within 2 years of the first, therefore, it is likely that most of our cohort are true incident cases.

To conclude, our study shows that BC and Ontario have some of the highest rates of PoMS in the world. The incidence of PoMS and the incidence sex ratio was stable over the study period, while prevalence increased. Similar to adults, there is a female preponderance in PoMS. Our findings may facilitate resource allocation and planning for children with MS, including education supports, mental healthcare and rehabilitative services, as well as required services in the future as this vulnerable population ages. Further research is needed to evaluate the incidence and prevalence of PoMS in other world regions.

Multiple sclerosis

Disclaimer The analyses, conclusions, opinions and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred.

Competing interests FLAY is funded by a Fredrick Banting and Charles Best Canada Graduate Scholarship from the Canadian Institutes of Health Research (CIHR). KM receives research support from the Swedish Research Council for Health, Working Life and Welfare and a salary award from the Karolinska Institute. She has received speaker honoraria from Sanofi-Aventis and Biogen. RAM receives research funding from: the Canadian Institutes of Health Research, MS Canada, Multiple Sclerosis Scientific Foundation, Crohn’s and Colitis Canada, National Multiple Sclerosis Society, CMSC, the Arthritis Society and US Department of Defense. She is supported by the Waugh Family Chair in Multiple Sclerosis. She is a co-investigator on studies funded partly by Biogen Idec and Roche (no funds to her, her institution). CM receives research funding from a University of Waterloo Research Chair, CIHR, MS Canada, National Multiple Sclerosis Society, CMSC, the Ontario Neurodegenerative Disease Research Initiative and the Public Health Agency of Canada. HT has, in the last five years, received research support from the Canada Research Chair Program, the National Multiple Sclerosis Society, the Canadian Institutes of Health Research, MS Canada, the Multiple Sclerosis Research Foundation and the EMDUS Foundation (‘Fondation EMDUS contre la sclérose en plaques’). In addition, in the last 5 years, has had travel expenses or registration fees prepaid or reimbursed to present at CME conferences from the Consortium of MS Centres (2018, 2023), National MS Society (2018, 2022), ECTRIMS/ACTRIMS (2017-2023), American Academy of Neurology (2019). Speaker honoraria are either declined or donated to an MS charity or to an unrestricted grant for use by HT’s research group.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and the University of British Columbia’s Clinical Research Ethics Board approved the study (H20-03232). Patient consent was not required to access health administrative data in British Columbia and Ontario, Canada.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Access to data provided by the Data Steward(s) is subject to approval, but can be requested for research projects through the Data Steward(s) or their designated service providers. All inferences, opinions and conclusions drawn in this publication are those of the author(s), and do not reflect the opinions or policies of the Data Steward(s).

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iDs
Ruth Ann Marrie http://orcid.org/0000-0002-1855-5595
Kyla McKay http://orcid.org/0000-0002-9081-1522
Helen Tremlett http://orcid.org/0000-0001-5804-2535

REFERENCES