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Morbidities and mortality of diagnosed attention deficit hyperactivity disorder (ADHD) over the youth lifespan: A population-based retrospective cohort study

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Abstract

Objectives: To estimate the prevalence of ADHD, and related comorbidities, mortality, and type of health service use among children and young adults, using different case definitions.

Methods: We conducted a population-based retrospective cohort study between 2000 and 2018, using the Quebec Integrated Chronic Disease Surveillance System (QICDSS) database. All residents aged less than 25 years eligible for health insurance coverage were included. We compared outcomes of three indicators (morbidity, services use and mortality) according two different algorithms of ADHD definitions, to the general population.

Results: The cumulative prevalence of ADHD has risen steadily over the past decade, reaching 12.6% in 2017–2018. People with ADHD have a higher prevalence of psychiatric comorbidities, make greater use of medical, mental health services, and are hospitalized more often. The comparison of prevalence between the two algorithms and the general population for the three indicators showed that the cohort having one claim was very close to that with two or more, and statistically significant higher to that of people without ADHD.

Conclusion: This finding support that a single claim algorithm for ADHD can be used for case definition. More research is needed on the impact of potentially effective treatments in improving consequences of ADHD.

KEYWORDS
ADHD, child psychiatric, comorbidity, epidemiology, health services

1 | INTRODUCTION

The American Centre for Disease Control and Prevention (CDC) reported that the prevalence of physician diagnosed attention deficit disorder with or without hyperactivity (ADHD) in US children aged 4 to 17 years old, as reported by parents, has risen by more than a third, from 7.5% to 10.8%, between 2002 and 2017 (Centers for Disease Control and Prevention, 2018). The prevalence of ADHD has also been increased in other countries, varying considerably according to data sources, reaching up to 5% for annual prevalence (Hauck et al., 2017; Lecendreux et al., 2011) and 11% for lifetime prevalence (Centers for Disease Control and Prevention, 2019; Diallo et al., 2019). In Canada, the annual prevalence of diagnosed ADHD in 2011–2012 among children aged 1 to 17 years of age ranged between 1.1% and 3.8% according to the province when consulting medico-administrative databases (Vasiliadis et al., 2017). Others estimated the annual prevalence of diagnosed ADHD at 5.4% in people aged 24 and under using the Ontario Electronic Medical Record Administrative Data Linked Database (EMRALD; Hauck et al., 2017). A recent epidemiologic study using standardized questionnaires conducted in Ontario school children reported past 6-month prevalence estimates of 10.5% and 6.8% for children aged 4 to 11 years and 12 to 17 years when families were surveyed (Georgiades et al., 2019).

Psychiatric and physical comorbidities are more prevalent among individuals with ADHD (Aduen et al., 2018; Brandt et al., 2018; Chen et al., 2018; Cortese et al., 2016; Cortese, Sun, et al., 2018; Joelsson et al., 2016; Sabuncuoglu, 2013; Schans et al., 2017; Yang et al., 2007), and their pattern changes throughout the lifespan (Franke et al., 2018). Attention deficit hyperactivity disorder (ADHD) affects academic performance and professional success, as well as the daily functioning within the family and the society (AlZaben et al., 2018; Franke et al., 2018; Lecendreux et al., 2011; Owens et al., 2017). Treatment of ADHD has been shown to reduce symptoms and impairment (Franke et al., 2018). Effective treatments of ADHD include medication (Cortese, Adamo, et al., 2018; Georgiades et al., 2019), behavior therapy and symptoms management with the support of parents and schools (Centers for Disease Control and Prevention, 2020). Among U.S. children aged 2 to 17 years who received an ADHD diagnosis, 62% were taking medication, and 47% were undergoing behavioral treatment (Centers for Disease Control and Prevention, 2019). Parents in Ontario reported that about two-thirds of children aged 6 to 11 years and those aged 12 to 17 received health services primarily in the school services, followed by the primary care sector and to a lesser extent from the specialty mental health sector (Georgiades et al., 2019).

The societal burden associated with ADHD related to its symptoms and functional impairment that can persist into adulthood underlines the importance of its routine surveillance in populations. The monitoring of ADHD diagnosis, receipt of medical care, comorbidities, and mortality are crucial for timely policy making in the Canadian health system context. Administrative databases can be used as effective monitoring tools providing timely information on individuals with ADHD. However, medico-administrative data files are designed for administrative purposes, and reporting of diagnoses may be subject to recording biases. In Canada, the diagnosis of ADHD is generally made by family physicians and pediatricians who may not have sufficient time to consider all diagnostic criteria during one medical visit (Davis et al., 2016). Case definitions for chronic disorders, such as hypertension and diabetes, are often based on algorithms of diagnoses and therapeutic codes and outcomes such as hospitalizations (The Lancet, 2019). In the case of ADHD, the data captured by the Canadian Chronic diseases surveillance systems (CCDSS), with Quebec Integrated Chronic Diseases Surveillance System (QICDSS), participating in the CCDSS, can be useful for defining cases of ADHD and their routine monitoring for informing policy and decision-makers.

The objectives of this study were therefore to (1) estimate the cumulative prevalence of diagnosed ADHD using the QICDSS databases; (2) estimate lifetime comorbidities, mortality, and services use of children and younger adults aged less than 25 years according to the presence of ADHD; and (3) carry out sensitivity analyses to test the robustness of the proposed case definitions.

2 | METHODS

2.1 | Study design, data sources, and case identification

We conducted a population-based retrospective cohort study analyzing the QICDSS dataset. Quebec's universal health care system, based on a fee-for-service medical care model, allows the QICDSS to have complete medical care data on all Quebec residents eligible for provincial health insurance. This dataset links physician claims, hospital discharge, death registry and health insurance registry records starting from January 1, 1996 (Blais et al., 2014). The physician claims database includes dates of service, diagnosis, and specialty of the physician seen. The hospitalization discharge database consists of the admission diagnosis, primary diagnosis and up to 25 secondary diagnoses. The health insurance registry provides information on demographics and health insurance eligibility. Diagnostic codes in physician claims data during the study period are based on the ninth revision of the International Classification of Diseases (ICD-9). Diagnostic information in the hospitalization database was coded using ICD-9 prior to 2006 and ICD-10 afterward.

The study population included all residents aged up to 24 years and eligible for health insurance coverage. To be considered as having a diagnosis of ADHD, an individual had to have at least one physician claim or hospital discharge abstract from 2000 to 2018 with a primary ADHD diagnosis (ICD-9 codes 314 or their equivalent ICD-10-CA). The following case definitions were studied for comparison purposes on the three indicators (comorbidities, services uses

and mortality): (1) those identified by the algorithm demanding only one claim within 5 years (Cohort 1); (2) those identified by the algorithm requiring at least two claims spaced more than 30 days within 5 years (Cohort 2).

The ICD-9 codes used to identify comorbid conditions are presented in Table 1 (see first column). A systematic scan and review of the literature guided the choice of comorbidities to be studied. The mental health service utilization profiles were constructed based on the location where the services were provided and according to the specialization of the physician involved. A distinction was made between office and hospital-based care, and the latter subdivided into outpatient appointments, emergency room visits or inpatient care. We used the following hierarchy to characterize health service use: (a) inpatient hospital care; (b) inpatient health and social youth centers; (c) emergency room visits; (d) outpatient psychiatric contacts; (e) outpatient pediatric contacts; (f) general practitioner office; and (g) another medical specialist. Hospital data took precedence over community-based care, and inpatient data took precedence over outpatient data. This hierarchy considered that a given individual could consult various professionals or use various health services over a given period.

2.2 | Statistical analysis

Prevalence, comorbidity and service use were calculated yearly for fiscal years from 2000 to 2018 (fiscal year started April 1st and ended on March 31st), whereas mortality was measured from Apr. 1, 2000, to Mar. 31, 2017, due to a delay in the validation of the death database. Comparisons over time were made using age-adjusted measures. Rates were directly standardized according to the age structure of the population of Quebec in 2001. Estimates are presented with their 99% CI. Non-overlapping 99% CI were interpreted as estimates being statistically different. The cumulative prevalence of people who had at least one claim during their lifetime (i.e., the individual only had to meet the inclusion criteria once during the period of observation in order to be considered a prevalent case of ADHD) and two claims within 5 years were presented. To appreciate the impact of the different ADHD case definitions (sensitivity analysis), comparisons were carried out between the two case definitions and the general population. Individuals with only one claim in 5 years and those with at least two claims in 5 years were both compared to individuals without an ADHD diagnosis. These sensitivity analyses were performed for the presence of comorbidities, mental health service utilization and

TABLE 1 Comorbidities of people aged 1–24 years, with and without attention deficit hyperactivity disorder (ADHD), in lifetime, Quebec, 2017–2018

Comorbidity (ICD-9 codes)	With ADHD (1 claim—Cohort 1; n = 80,755)		With ADHD (at least 2 claims—Cohort 2; n = 182,840)		Without ADHD (n = 1,906,450)	
	Prev (%)	99% CI	Prev (%)	99% CI	Prev (%)	99% CI
Diseases of the respiratory system (460–519)	93.2	92.2–94.3	94.5	93.0–96.0	83.0	82.9–83.2
Trauma (800–999)	74.9	74.0–75.8	77.0	75.8–78.2	61.8	61.6–61.9
Infectious diseases (000–139)	70.0	69.1–70.9	71.4	70.2–72.6	57.6	57.4–57.7
Diseases of the genito-urinary system (580–629)	42.5	41.9–43.2	42.4	41.8–43.0	33.7	33.6–33.8
Congenital anomalies (740–759)	37.8	37.1–38.5	39.9	38.9–40.9	19.9	19.8–20.0
Tumors (140–239)	21.8	21.4–22.2	32.3	31.2–33.5	11.1	11.0–11.1
Epilepsy (345)	5.3	5.0–5.5	6.6	6.1–7.1	1.4	1.4–1.4
Down syndrome (758)	1.9	1.7–2.1	2.2	1.9–2.6	0.6	0.6–0.6
Mental disorders (290–319)	35.2	34.6–35.7	49.1	47.8–50.5	24.6	24.5–24.7
Anxio-depressive disorders (296,300, 311, and 313)	30.0	29.3–30.7	24.7	24.3–25.1	11.8	11.8–11.9
Developmental delay (315 and 317–319)	14.3	14.0–14.7	23.4	22.6–24.3	6.8	6.7–6.8
Reactive disorders (308–309)	11.5	11.1–11.9	12.4	11.9–12.8	4.0	3.9–4.0
Behavioral disorders (301, 302, and 312)	7.9	7.6–8.2	11.8	11.2–12.4	2.2	2.2–2.2
Substance use disorders (291–292 and 303–305)	3.5	3.3–3.7	4.5	4.3–4.8	1.4	1.3–1.4
Autism spectrum disorders (299)	3.7	3.5–3.9	4.3	3.8–4.7	0.9	0.9–0.9
Intellectual disability (317–319)	1.7	1.5–1.9	1.7	1.4–2.1	0.2	0.2–0.3
Organic psychosis (290–294)	1.3	1.2–1.5	1.5	1.2–1.7	0.6	0.6–0.6
Schizophrenia (295)	0.5	0.5–0.6	0.7	0.6–0.8	0.2	0.2–0.2

Abbreviation: ADHD, attention deficit hyperactivity disorder.

mortality. The analyses of excess mortality by main cause of death for persons with ADHD were calculated using age-adjusted mortality rate ratios and are presented according to ADHD status. It should be noted that analyses performed with these two case definitions were mutually exclusive, for comparative purposes.

2.3 | Ethics approval

The project was approved by the Montreal Mental Health University Institute. Also, the QICDSS utilization has been approved by government bodies, the Public Health Ethics *Committee and the Commission d'accès à l'information du Québec* (Quebec information and privacy commission).

3 | RESULTS

From the QICDSS dataset, 2,170,045 individuals met inclusion criteria in 2017–2018 (49% female and 51% male). The population aged 1 to 11, 12 to 17, and 18 to 24 years comprised 46%, 22%, and 32% of the population, respectively. Among these eligible people,

263,595 received a diagnosis of ADHD broken down as follows: 80,755 had one claim in 5 years, and 182,840 had at least two claims separated by more than 30 days within 5 years.

3.1 | Prevalence of ADHD

In 2017–2018, the cumulative prevalence with at least one claim during the study period was 12.6% (*n* = 263,595; Graph 1). Boys were most often diagnosed, and this at a rate two times that of girls. The prevalence also differed according to the age groups 1–11, 12–17, and 18–24 years, which reached 6.6%, 18.9%, and 15.5%, respectively, in 2017–2018 (results not shown).

3.2 | Comorbidity associated with ADHD

Table 1 presents the lifetime psychiatric and physical comorbidities diagnosed in children and young adults with and without ADHD during the study period. The results show that for ADHD case definitions, one claim and two claims in 5 years, the prevalence of psychiatric and physical comorbidities was higher than that in the general population.
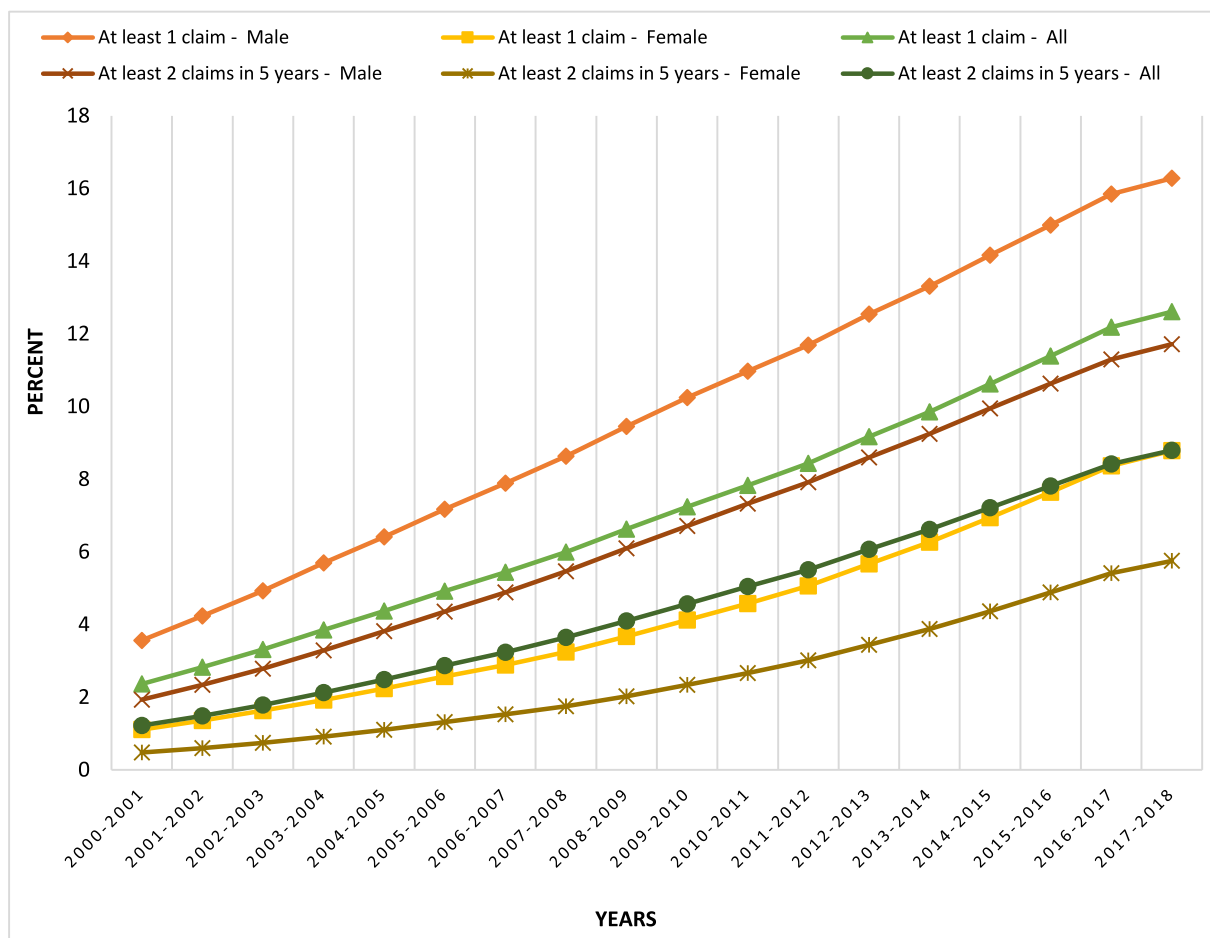
GRAPH 1 Cumulative prevalence of diagnosed attention deficit hyperactivity disorder (ADHD) of people aged 1–24 years (at least one claim in life and two claims in 5 years), by sex and year

When comparing comorbidities between the case definitions, the frequency of psychiatric comorbidities was generally higher among people with two ADHD claims than those with one claim.

3.3 | Service utilization

Graph 2 presents the hierarchical mental health service utilization in 2017–2018. After 18 years old, individuals with ADHD received fewer mental health services and the role of family physicians increased. They were more likely than the general population to be hospitalized or seen in emergency settings. The pattern applied to both ADHD algorithms used, with the two claims definition being associated with a greater utilization than the one claim definition.

3.4 | Measuring excess mortality

Table 2 shows the mortality rate among persons aged 1–24 years with and without ADHD for the period from 2000 to 2017. The overall mortality was higher for ADHD than the general population. This also applies to the one claim and two claim case definitions with the exception for the two claims definition in the other causes of deaths.

4 | DISCUSSION

Our findings show that ADHD has risen steadily over the past decade, reaching a cumulative prevalence of 12.6% amongst people 24 years and younger during the study period ending in 2017–2018. These data are aligned with existing literature on diagnosed prevalence drawn from linked health administrative databases (Centers for Disease Control and Prevention, 2019; Diallo et al., 2019) and to epidemiological surveys (Georgiades et al., 2019), when a case definition relies on one claim in life. The predominance of boys over girls is consistent with the results from previous studies (Diallo et al., 2019; Franke et al., 2018; Hauck et al., 2017; Vasiliadis et al., 2017; Visser et al., 2007). There was a variation in prevalence rates across age groups: people aged 12 to
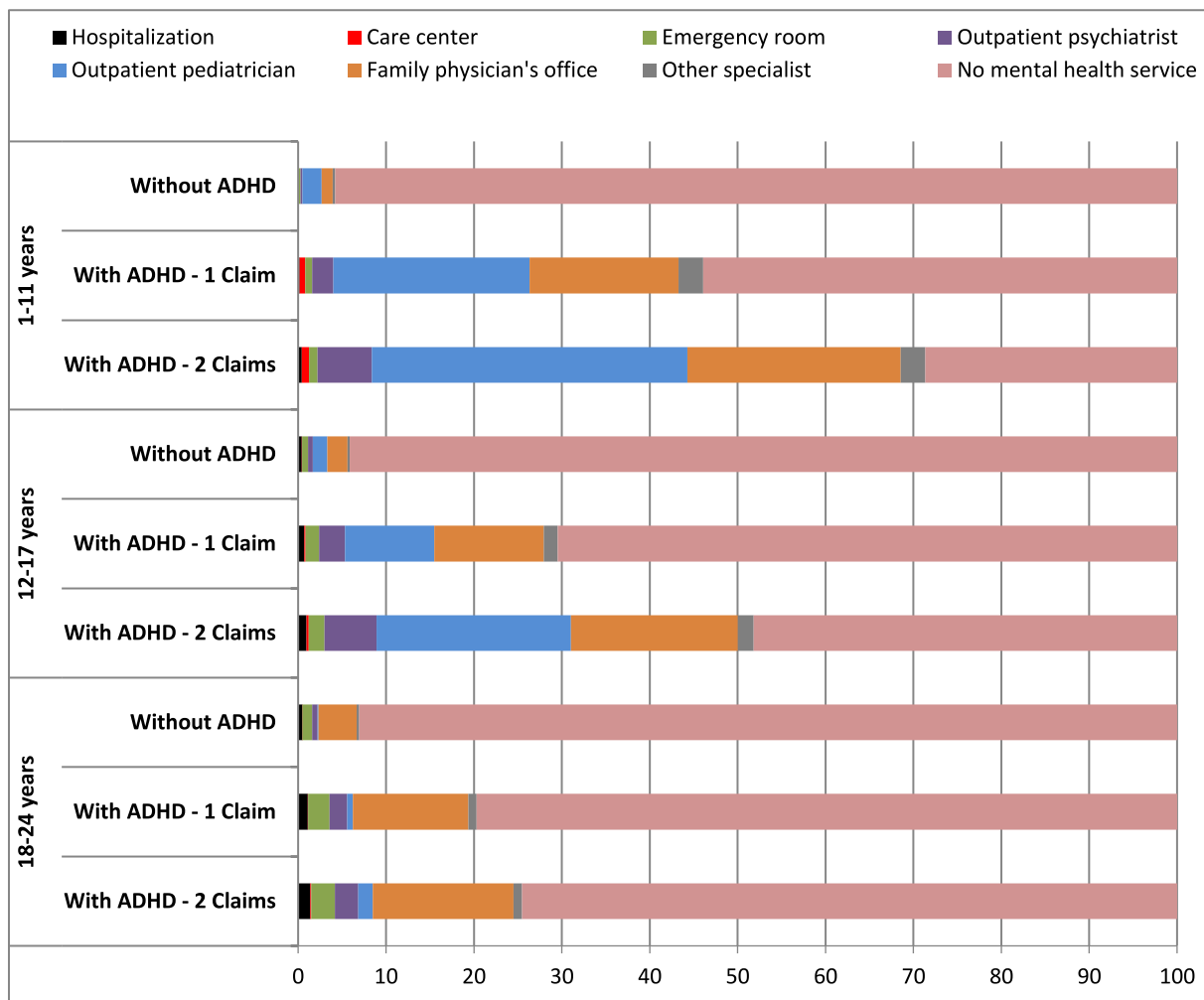
GRAPH 2 Hierarchical mental health service utilization profile of persons with and without attention deficit hyperactivity disorder (ADHD), by age group, 2017–2018

TABLE 2 Mortality rate (per 100,000) by cause of death for persons aged 1 to 24 years with or without diagnosed attention deficit hyperactivity disorder (ADHD), Québec, 2000–2017

	Mortality rate (per 100,000 and 99% CI)					
	1–17 years			**18–24 years**		
Cause of death	**Without ADHD**	**With 1 claim (Cohort 1)**	**With 2 claims (Cohort 2)**	**Without ADHD**	**With 1 claim (Cohort 1)**	**With 2 claims (Cohort 2)**
Total	13.5 (12.9–14.1)	21.8 (17.4–26.9)	18.9 (15.8–22.4)	43.1 (41.5–44.6)	55.0 (44.6–66.9)	54.1 (46.3–62.8)
Suicide	1.6 (1.4–1.8)	3.3 (1.8–5.6)	2.7 (1.6–4.2)	12.3 (11.4–13.1)	14.6 (9.5–21.2)	15.7 (11.7–20.7)
Trauma without suicide	5.0 (4.6–5.3)	5.8 (3.7–8.7)	7.3 (5.5–9.6)	19.8 (18.7–20.9)	26.5 (19.5–35.1)	28.5 (23.0–35.0)
Others causes of death	7.0 (6.5–7.4)	12.7 (9.4–16.7)	8.9 (6.8–11.3)	11.0 (10.2–11.8)	13.9 (9.0–20.5)	9.8 (6.7–13.9)

Abbreviation: ADHD, attention deficit hyperactivity disorder.

17 years registering the most significant difference followed by the 18- to 24-year and the 1- to 11-year groups. This difference persisted no matter the case definition used. Rates have been shown to also vary by age in the United States (Centers for Disease Control and Prevention, 2019). The ADHD cumulative prevalence gap between the one claim in the lifetime group (12.6%) and the two claims in 5 years group (8.8%) should not be interpreted as false positives cases. In fact, many of these individuals may represent individuals who were not medically followed. Therefore, we could argue that the algorithm with one claim is valid and enforceable for cumulative prevalence.

As reported in other studies, people with ADHD are more likely to have psychiatric and physical comorbidities (Aduen et al., 2018; Brandt et al., 2018; Cortese et al., 2016; Cortese, Sun, et al., 2018; Cuffe et al., 2015; Diallo et al., 2019; Franke et al., 2018; Hauck et al., 2017; Joelsson et al., 2016; Schans et al., 2017; Yang et al., 2007). In this study, the prevalence rate of comorbidities was highest for people with two claims compared to those with one claim within 5 years. One could assume that people with two or more claims may present more severe profiles and also have concomitant illnesses leading to more follow-up care. In addition, people with ADHD made greater use of medical mental health services and were hospitalized more often for mental health reasons than the general population and this no matter the case definition used. This was also expected given the higher rates of comorbidities with different mental disorders. As we review the hierarchical use of mental health services, we found that the majority of people with ADHD were followed by pediatricians and general practitioners. As they reach the age of 18 years old, this pattern changes with a decline in overall service utilization for mental health reasons. This finding echoes concern expressed in the literature that the transition to adulthood is associated with a breach in the continuity of care in people with ADHD (Diallo et al., 2019; Franke et al., 2018). Another possible explanation could be that the core symptoms of ADHD improve to such an extent over time so that subjects no longer require specialized services.

Furthermore, our research supports what is observed in the literature by showing that the proportion of deaths among people with ADHD is higher than the general population (Barbaresi et al., 2013; Dalsgaard et al., 2015). While comparing the study groups, the one claim versus two claims case groups were not statistically significantly different (99% CI overlap), but both did differ from the general population group. This supports the case detection capacity of such a definition in linked health administrative databases.

Finally, the current study also contributed to the literature by carrying out sensitivity analyses to determine the impact of using different ADHD case definitions. We compared the prevalence of morbidities, service utilization and mortality rate for people with one claim for ADHD versus those having two claims or more in 5 years. The results showed that, for these three indicators, the cohort having one claim was very similar to the two or more claim group compared to people without ADHD. These data support that a single claim for ADHD can be used for case definition. Similarly, several studies based on case records examination used similar algorithms to distinguish between cases and non-cases and reported their sensibility (Jean et al., 2012; Southern et al., 2010).

4.1 | Limitations

The QICDSS constitutes an inestimable source of information for the surveillance of ADHD, given that it documents all healthcare services used by the Quebec population (Blais et al., 2014). However, our results need to be considered while taking into account the following limitations. First, as the QICDSS was designed for administrative purposes, it may be subject to a recording bias, especially regarding diagnosis. We partly addressed this issue by comparing the results from two ADHD algorithms. Moreover, the identification of physical conditions using QICDSS data has shown high validity (Lambert et al., 2012). Second, since QICDSS data only include information on people who use health care services, the case definition only identifies people who have received a diagnosis or treatment from a physician. Several studies have shown that diagnoses recorded in medical records fully correspond to entries in administrative databases for other

diseases, in Quebec as in other provinces (Jean et al., 2012; Ouhoummane, 2010). This suggests that the QICDSS is a useful monitoring tool for identifying temporal trends among treated cases. Finally, it is difficult to affirm generalizability of our results because we studied only Quebec residents. However, a cross-provincial comparison of annual prevalence using their linked health administrative databases showed the feasibility of the case definition, and variation in annual treated prevalence (Vasiliadis et al., 2017). This study could serve as a reference for other Canadian provinces and the Canadian Chronic Disease surveillance system and other developed countries with linked health administrative databases.

5 | CONCLUSION

Our study confirms that the prevalence of ADHD has risen steadily over time with significant variations by sex and age group. This study also allowed to identify the comorbidities associated with ADHD and the measurement of health service utilization across the life trajectory, but also shed light on the specific needs of people with ADHD and on possible discontinuity of care in the service offer and a higher mortality rate. It also demonstrates the QICDSS's capacity to reliably monitor diagnosed and those possibly medically treated with ADHD medication. The current study showed that no matter the case definition used to identify treated ADHD cases, the QICDSS constitutes a useful database for health outcomes monitoring. Our results may have implications for future research. This includes exploring the underlying reasons for somatic comorbidities and their interaction with ADHD. Further research questions may also examine the impact of potentially effective treatments, such as ADHD medications, on the co-morbidities and long-term harmful consequences of ADHD.

CONFLICT OF INTEREST
The authors have no conflict of interest or financial relationship relevant to this article to disclose.

DATA AVAILABILITY STATEMENT
We will not be able to let data go anywhere. We do not have permission to share the data from Quebec Integrated Chronic Diseases Surveillance System (QICDSS).

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