BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-067689
Article Type:	Original research
Date Submitted by the Author:	23-Aug-2022
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Keywords:	COVID-19, Dementia < NEUROLOGY, Public health < INFECTIOUS DISEASES, GERIATRIC MEDICINE

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Examining the immediate and on-going impact of the COVID-19 pandemic on population-based estimates of dementia

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Word count: 2,477

ABSTRACT

Objectives

Population-based chronic disease surveillance systems were likely disrupted by the COVID-19 pandemic. The objective of this study was to examine the immediate and on-going impact of COVID-19 pandemic on the claims-based incidence of dementia.

Methods

We conducted a population-based time series analysis from January 2015 to December 2021 in Ontario, Canada. We calculated the monthly claims-based incidence of dementia using a validated case ascertainment algorithm drawing from routinely-collected health administrative data. We used autoregressive linear models to compare the claims-based incidence of dementia during the COVID-19 period (2020-2021) to the expected incidence had the pandemic not occurred, controlling for seasonality and secular trends. We examined incidence by source of ascertainment and across strata of sex, age, and community size.

Results

The monthly claims-based incidence of dementia dropped from a 2019 average of 11.9 per 10,000 to 8.5 per 10,000 in April 2020 (32.6% lower than expected). Incidence returned to expected levels by late 2020. Across the COVID-19 period there were a cumulative 2,985 (95% CI [2,155-3,715]) fewer cases of dementia observed than expected, equivalent to 1.04 months of new cases. Despite the overall recovery, ascertainment rates continued to be lower than expected among individuals aged 65-74 years and in large urban areas.

Conclusions

The claims-based incidence of dementia recovered to expected levels by late 2020, suggesting minimal long-term changes to population-based dementia surveillance. Continued monitoring of claims-based incidence is necessary to determine whether the on-going lower than expected incidence among individuals 65-74 and in large urban areas is transitory.

Keywords: COVID-19, dementia, administrative data, chronic disease surveillance

Strengths and Limitations

- The population-based design enables examination of the research question over a large and representative population.
- The validated case ascertainment algorithm used in the study draws on health system encounters from multiple sectors.
- However, chronic disease ascertainment dates derived from health administrative data may not align with the date of clinical diagnosis.

INTRODUCTION

Dementia case ascertainment algorithms based on health administrative data are regularly used in population-based research and chronic disease surveillance.[1–3] By tracking the incidence and prevalence of diseases over time, chronic disease surveillance systems provide critical information for public health planning and evaluation.[4] In the absence of national registries or screening programs, administrative databases are a vital source of data on the epidemiology of chronic diseases.[5] Claims-based case ascertainment methods for dementia combine information gathered from routinely-collected health records, including physician encounters, hospital admissions, and dementia-specific medication use, to identify individuals who are likely to have been diagnosed with dementia. The performance of these algorithms varies by setting and jurisdiction, but they typically achieve high positive predictive value with reasonable sensitivity [6]. While these algorithms have clear utility, there are also known challenges as the methods depend on interactions with the health system which can be used to identify dementia diagnoses.[7] Accurate ascertainment requires equitable and consistent access to health services and recording of relevant diagnoses.

The extent and longevity of any impact of the COVID-19 pandemic on claims-based incidence of dementia has important implications for the use of population-based dementia estimates. A temporary drop in the claims-based incidence due to lockdowns, avoidance of in-person visits, and reduced access to community-based physician care may amount to a mere historical anomaly. However, given the upheaval in health service use during the pandemic, including the rapid uptake of virtual care[8] and changes in the diagnostic reasons for visits[9], long-term impacts to population-based dementia estimates are certainly plausible. Evidence of persistent change in claims-based incidence may indicate that the ability of the case ascertainment algorithm to identify persons with dementia has been altered and limit the comparison of population-based dementia estimates over time. The objective of this study was to examine how the claims-based incidence of dementia changed across the COVID-19 period in Ontario, Canada, both immediately at the start of the pandemic, as well as over time. We examined

differences in the claims-based incidence across contributing data sources (physician encounters, hospital admissions, medications) and across sociodemographic strata of age, sex, and community size.

METHODS

Setting and Study Design

We conducted a time series analysis using population-based health administrative datasets in Ontario, Canada. Ontario has a population of approximately 15 million individuals, including more than 2 million over the age of 65 years.[10] Ontario's health system includes publicly-funded universal health insurance for medically necessary services, including physician care, hospital-based care, and medication coverage for individuals aged 65 years and older.

Population

Our population was an open cohort of older adults 65 years at risk of dementia. We included older adults living in both community and congregate care settings.

Dementia case ascertainment

We used the dementia case definition from the Canadian Chronic Disease Surveillance System.[11] The validated algorithm identifies individuals likely diagnosed with dementia using the following criteria: 1.) three separate physician encounters with a dementia ICD-9/10 code, each at least one month apart; or 2.) a single hospital admission with a dementia ICD-9/10 code; or 3.) a single dispensation of a dementia-specific medication. The ascertainment date is identified as the earliest of the hospital admission date, the medication dispensation date, or the last date of the physician encounter sequence. A full definition of the algorithm including all ICD-9/10 codes and drug identification numbers is listed in Supplemental Table 1. In Ontario, the algorithm has been

validated in a primary care setting with a sensitivity of 79.3%, a specificity of 99.1%, and a positive predictive value of 80.4%.[12]

Data sources

Diagnosis codes from physician encounters and hospital admissions were extracted from the Ontario Health Insurance Plan database and the Canadian Institute for Health Information's Discharge Abstract Database, respectively. Medication use was captured from the Ontario Drug Benefit database. Ontario's insurable population was identified using the Registered Persons Database. These datasets were linked using unique encoded identifiers and analyzed at ICES. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement.

Claims-based incidence of dementia

We calculated the monthly claims-based incidence of dementia per 10,000 individuals among older adults (65+ years) in Ontario at risk of dementia between January 2015 to December 2021. The incidence was calculated as the number of new ascertainments in a month, divided by the population at risk of dementia at the start of the month, divided by the count of days in the month, multiplied by 30.

Statistical analysis

We fit autoregressive linear regression models to the monthly claims-based dementia incidence. The model was fit on the pre-COVID-19 pandemic period (2015 to 2019), controlling for seasonality via a categorical variable for month and secular trend via a linear term on the number of months since beginning of the time series. This model was used to generate the expected incidence of claims-based dementia from 2020-2021 (COVID-19 period), had the pandemic not occurred. We calculated relative and absolute differences between observed and expected claims-based dementia incidence. We characterized the initial decline in claims-based incidence by

comparing the observed and expected incidence at the month of the lowest observed incidence in 2020. We calculated the difference between the count of observed and expected dementia case ascertainments by applying the difference between the between the observed and expected incidences to the population at risk each month. We examined cumulative differences in the count of observed and expected dementia case ascertainments within calendar years and across the entire COVID-19 period. We constructed 95% confidence intervals around the cumulative differences in case ascertainments during the COVID-19 period using a 5000-replicate block bootstrap[13] with a block size of 3 months. To facilitate comparison across strata of different sizes, we expressed the cumulative difference in case ascertainments in terms of the number of months of new ascertainments they represent based on 2019 figures.

We stratified the main analysis by data source (physician encounters, hospital admissions, medications) to identify whether certain sources were more strongly affected by the pandemic. We additionally stratified by age (65-74,75-84,85+, sex (male vs. female), and community size (large urban, small urban, rural) to explore differential effects across sociodemographic strata. Community size was defined using the Rurality Index of Ontario[14]. All analyses were performed using R version 4.0.3.[15]

Sensitivity analysis

To examine whether any changes in claims-based incidence were specific to dementia, we repeated the analysis on the claims-based incidence of diabetes in older adults.[16] Diabetes was chosen as based on the similarity of the diabetes algorithm to that of the dementia algorithm.

Patient and Public Involvement

No patients were involved at the conduct of this study due to limited time and resources. We have invited patients and stakeholders to help us develop and carry out our knowledge dissemination strategy.

RESULTS

The population of the older adults at risk of dementia varied from 2,030,431 (January 2015) to 2,569,017 (December 2021). The monthly claims-based incidence of dementia declined slightly across the pre-COVID-19 period from an average of 12.5 cases per 10,000 in 2015 to 11.9 cases per 10,000 in 2019. Physician encounters were the most common source of case ascertainment across the entire time series, representing approximately 50% of new cases. Claims-based incidence dropped sharply during the first months of the COVID-19 period reaching a nadir of 8.5 per 1,000 in April 2020 (32.6% less than expected) (Table 1). By late 2020, the observed incidence had returned to the pre-pandemic expected incidence but did not rebound above expected levels (Figure 1).

Table 1. Observed and expected claims-based dementia incidence with relative and absolute differences, Jan 2020 to Dec 2021, Ontario, Canada

Month	Observed incidence	Expected incidence	Relative difference	Absolute difference in cases1,2	Cumulative difference in cases since Jan 2020	Cumulative difference in months of expected cases3
Jan-20	12.5	12.1	3%	94	94	0.03
Feb-20	10.5	11.5	-8%	-225	-130	-0.05
Mar-20	9.3	11.5	-19%	-540	-671	-0.23
Apr-20	8.5	12.6	-33%	-1012	-1683	-0.59
May-20	9.0	12.2	-26%	-780	-2463	-0.86
Jun-20	10.2	12.2	-17%	-501	-2964	-1.04
Jul-20	10.7	11.3	-6%	-161	-3125	-1.09
Aug-20	10.1	10.9	-8%	-213	-3338	-1.17
Sep-20	11.5	11.6	-1%	-30	-3368	-1.18
Oct-20	11.5	11.8	-3%	-77	-3445	-1.21
Nov-20	11.9	12.4	-4%	-114	-3559	-1.25
Dec-20	10.7	10.3	4%	110	-3450	-1.21
Jan-21	10.9	11.9	-8%	-250	-3700	-1.29
Feb-21	11.5	11.3	1%	43	-3657	-1.28
Mar-21	12.6	11.4	11%	311	-3346	-1.17
Apr-21	11.7	12.5	-6%	-191	-3536	-1.24
May-21	11.4	12.0	-6%	-172	-3708	-1.30
Jun-21	12.6	12.0	5%	148	-3560	-1.25
Jul-21	11.1	11.2	-1%	-20	-3581	-1.25
Aug-21	11.2	10.8	4%	106	-3474	-1.22
Sep-21	11.9	11.4	4%	129	-3345	-1.17
Oct-21	12.0	11.7	3%	80	-3266	-1.14
Nov-21	13.0	12.2	6%	205	-3061	-1.07
Dec-21	10.4	10.1	3%	76	-2985	-1.04
2020 Cumulative difference in cases (95%CI)					-3,449 (-3768,-3,099)	

2021 Cumulative difference in cases (95%CI)	465 (43, 929)
2020-2021 Cumulative difference in cases (95%CI)	-2,985 (-3,715-2,155)

1. Calculated as difference between observed and expected incidence multiplied by population at risk of dementia, rounded to whole number
2. Rounded to whole number
3. Based on monthly average of new ascertainments in 2019

Between January 2020 and December 2021, there were a cumulative 2,985 (95% CI: 2,155-3,715) fewer case ascertainments observed than expected, a gap equivalent to 1.04 months of cases based on 2019 averages. The vast majority of the fewer-than-expected ascertainments were accumulated between February 2020 and June 2020. Across 2021 as a whole, there were slightly more cases observed than expected (465 cases (95% CI: 43, 929)). In each of the final five months of the time series, the observed count exceeded the expected count by 3%-6% (Table 1).

All data sources exhibited drops in claims-based incidence during the first months of the pandemic, with medication use demonstrating the largest relative decrease (59.4%) in April 2020, compared to 26.9% for physician encounters, and 27.4% for hospital admissions (Figure 2, Table 2). After the initial decline, ascertainments in the hospital setting recovered the quickest, followed by medication use. Throughout 2021, observed case ascertainment from physician encounters continued to lag behind expected ascertainments, while observed ascertainments in the other settings exceeded the expected number of cases.

Table 2. Changes in the claims-based dementia incidence during the COVID-19 pandemic with cumulative differences between observed and expected cases, by data source, sex, age, and community size, in Ontario, Canada

Measure	Overall	Data source		
		Physician encounters	Hospital admissions	Medication use
2019 Average incidence / 10,000	11.9	6.2	2.9	2.7
2020 Nadir incidence / 10,000	8.5	4.9	2.1	1.1
Percent drop in incidence at nadir vs. expected	32.6%	26.9%	27.4%	59.4%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.63 (-1.53, 1.41)	0.32 (-0.03, 0.72)	-1.78 (-2.19, -1.38)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-1.23 (-1.52, -0.94)	1.90 (1.43, 2.45)	1.51 (0.96, 2.04)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.04 (-1.29, -0.74)	-2.86 (-3.36, -2.35)	2.23 (1.38, 3.17)	-0.27 (-1.23, 0.66)

Measure	Overall	Sex	
		Male	Female
2019 Average incidence / 10,000	11.9	10.7	12.9
2020 Nadir incidence / 10,000	8.5	7.4	9.4
Percent drop in incidence at nadir vs. expected	32.6%	34.6%	31.1%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.06 (-1.23, -0.88)	-1.32 (-1.47, -1.16)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	0.32 (0.10, 0.55)	0.04 (-0.16, 0.26)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.04 (-1.29, -0.74)	-0.73 (-1.13, -0.33)	-1.28 (-1.63, -0.90)

Measure	Overall	Age		
		65-74	76-85	85+
2019 Average incidence / 10,000	11.9	3.7	15.9	42.4
2020 Nadir incidence / 10,000	8.5	2.7	10.8	31.5
Percent drop in incidence at nadir vs. expected	32.6%	30.1%	35.9%	30.1%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.37 (-1.63, -1.12)	-1.22 (-1.40, -1.03)	-1.05 (-1.24, -0.85)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.30 (-0.58, -0.03)	0.39 (0.14, 0.64)	0.22 (-0.04, 0.47)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.04 (-1.29, -0.74)	-1.67 (-2.26, -1.10)	-0.83 (-1.27, -0.40)	-0.83 (-1.29, 0.39)

		Community size

Measure	Overall	Large Urban	Small Urban	Rural
2019 Average incidence / 10,000	11.9	12.4	10.9	10.9
2020 Nadir incidence / 10,000	8.5	9.0	7.6	7.4
Percent drop in incidence at nadir vs. expected	32.6%	32.3%	32.3%	36.1%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.46 (-1.25, -1.54)	-0.53 (-0.24, -0.81)	-0.89 (-1.43, -0.33)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.20 (-0.36, -0.02)	0.94 (0.61, 1.30)	0.04 (-0.69, 0.77)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.04 (-1.29, -0.74)	-1.62 (-1.90, -1.26)	0.41 (-0.20, 0.90)	-0.86 (-2.11, 0.44)

1. Cumulative difference between observed and expected cases expressed in terms of the number of months of new cases based on 2019 figures

Analysis across sociodemographic strata

Initial declines in claims-based incidence across sociodemographic strata were broadly similar, with the smallest drop at 30.1% less than expected among individuals 85+ and the largest drop at 35.6% less than expected among individuals living in rural locations (Figure 2, Table 2). Recoveries were uneven however, and ascertainments in 2021 among individuals aged 65-74 and those residing in large urban locations tracked below expected levels, while ascertainments among those in small urban locations tracked significantly higher.

Sensitivity analysis

The claims-based incidence of diabetes exhibited a larger initial drop than dementia (50.5% less than expected) in April 2020 but returned to expected values along a similar timeline (Supplementary Table 2). However, the claims-based diabetes incidence consistently exceeded expected levels in 2021. Cumulative ascertainments during the COVID-19 period for diabetes turned positive in September 2021 and as of December 2021 there were 1.05 months more diabetes ascertainments more observed than expected.

DISCUSSION

We found that the claims-based incidence of dementia in Ontario dropped sharply at the start of the COVID-19 pandemic in 2020. Claims-based incidence returned to expected levels by the end of 2020 but did not appreciably rebound above the expected levels. As a result, across the entire pandemic period there have been significantly fewer dementia ascertainments observed than expected. Although the overall incidence returned to normal levels, ascertained cases via physician encounters, among individuals 65-74 years of age, and in large urban areas continued to lag behind expected counts.

The drop in the claims-based incidence of dementia in early 2020 mirrors the reductions in health service use that occurred at the same time[8,17,18]. The rapid return of the observed claims-based incidence to the expected incidence also tracks health service use rebound and broadly suggests no major long-term changes to the performance of the case ascertainment algorithms. However, unlike diabetes, the claims-based incidence of dementia did not rebound above expected levels in 2021 to eliminate the gap in ascertainments that accumulated across 2020. This small, but enduring, ascertainment gap and unevenness of the rebound across sociodemographic strata warrant continued close monitoring to determine whether these effects are transitory.

Between January 2020 and December 2021, the cumulative count of dementia ascertainments was roughly one months' worth of cases fewer than what we would have expected had the pandemic not occurred. Although the observed counts of dementia cases exceeded the expected counts in each of the final several months of 2021, the narrowing of the ascertainment gap has been slight. The trend in dementia cases stands in sharp contrast to the claims-based incidence of diabetes, which rebounded significantly above expected levels during 2021. One possible explanation for the persistent undercount in dementia cases is that the COVID-19 pandemic may have resulted in higher relative mortality rates among individuals at higher risk of developing dementia[19], for example residents of congregate care settings. This is at best at partial explanation however, as higher mortality cannot account for the dramatic shifts in the claims-based incidence that follow the decline and rebound in health service use. The ascertainment gap is more likely a result of changes in health-seeking behavior, patient access to health care services, and delivery of health services during the pandemic and recovery. Notably, we found that

ascertainments from physician encounters lagged expected counts throughout the entire pandemic period, despite the fact that overall physician visit volumes recovered to normal levels in 2020[20]. This may be related to the rapid uptake of virtual care as the challenges of performing cognitive testing virtually may initially lead to fewer or delayed diagnoses of dementia as physicians adapt to new tools[21,22]**.** Virtual care may also be less accessible to older adults living with frailty or without a caregiver[23]**.** Finally, ascertainments via physician encounters are more susceptible to disruption as the algorithm requires a specific number of visits within a specific time frame. An interruption in access may break the sequence of visits and delay ascertainment.

The on-going lower than expected claims-based incidence among individuals aged 65-74 is likely also related to health system disruption and recovery during the pandemic. Younger individuals utilize less care on average and experienced greater relative reductions in health service use during the pandemic compared to older individuals[20]. Therefore, it may take more time for the ascertainment rates for younger individuals to regain their normal levels. The lower than expected incidence within large urban areas is at a glance surprising as individuals within these areas typically have the greatest access to health care[24]. However, the shift to virtual visits was most pronounced in urban areas.[8] Additionally, urban areas were under strict public health measures for longer periods of time and therefore individuals in the these areas may have experienced longer delays in resuming normal health service use levels[25].

At a minimum, our findings indicate that the early months of the pandemic are a historical anomaly in population-based dementia estimates that will need to be accounted for in on-going dementia surveillance. Additionally, research studies that rely on claims-based dementia ascertainment to generate cohorts or define outcomes need to carefully consider the impact of the pandemic on their research. The difference between the trends in claims-based incidence of dementia and diabetes in our study also suggests the need to examine a broad set of chronic disease case ascertainment algorithms to determine how they differed during the COVID-19 era. As evidence emerges that that the likelihood of developing certain chronic diseases is increased following COVID-19 infections, monitoring a wide range of chronic diseases on a population level should be a public health priority.[26]

Limitations

Case ascertainments from administrative data are gleaned from health system encounters and therefore do not perfectly correspond to clinical diagnoses or necessarily represent the experience of the individual. Additionally, differences in the severity of COVID-19 pandemic and public health system response may result in differences in how population-based dementia estimates have changed across jurisdictions.

Conclusion

Claimed-based dementia incidence as estimated from routinely-collected data fell early in the COVID-19 pandemic but returned to expected levels by late 2020. However, as of the end of 2021 there were still significantly fewer cumulative dementia cases observed than expected across the pandemic period. Rates of case ascertainment were lower than expected among individuals 65-74 years old and in large urban areas even after health service use rebounded. Continued population-based monitoring of dementia incidence is necessary to identify whether these effects are transitory.

ETHICS APPROVAL STATEMENT

ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement. The use of the data in this project is authorized under section 45 of Ontario's Personal Health Information Protection Act (PHIPA) and does not require review by a Research Ethics Board.

DATA SHARING STATEMENT

The dataset from this study is held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the dataset publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at www.ices.on.ca/DAS. The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

CONTRIBUTORS

AJ, AC, and LG conceived the work. AJ developed the design and conducted all analyses. DK performed data curation. AJ wrote the initial draft. All authors contributed to the interpretation of the work and revised the work for critical intellectual content.

COMPETING INTERERSTS

None to report

FUNDING

This study received funding from the Public Health Agency of Canada (2021-HQ-000076). This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care.

DISCLAIMER

Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information. However, the analyses, conclusions, opinions, and statements expressed in the material are those of the author(s), and not necessarily those of the Canadian Institute for Health Information. 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. We thank IQVIA Solutions Canada Inc for use of their Drug Information File.

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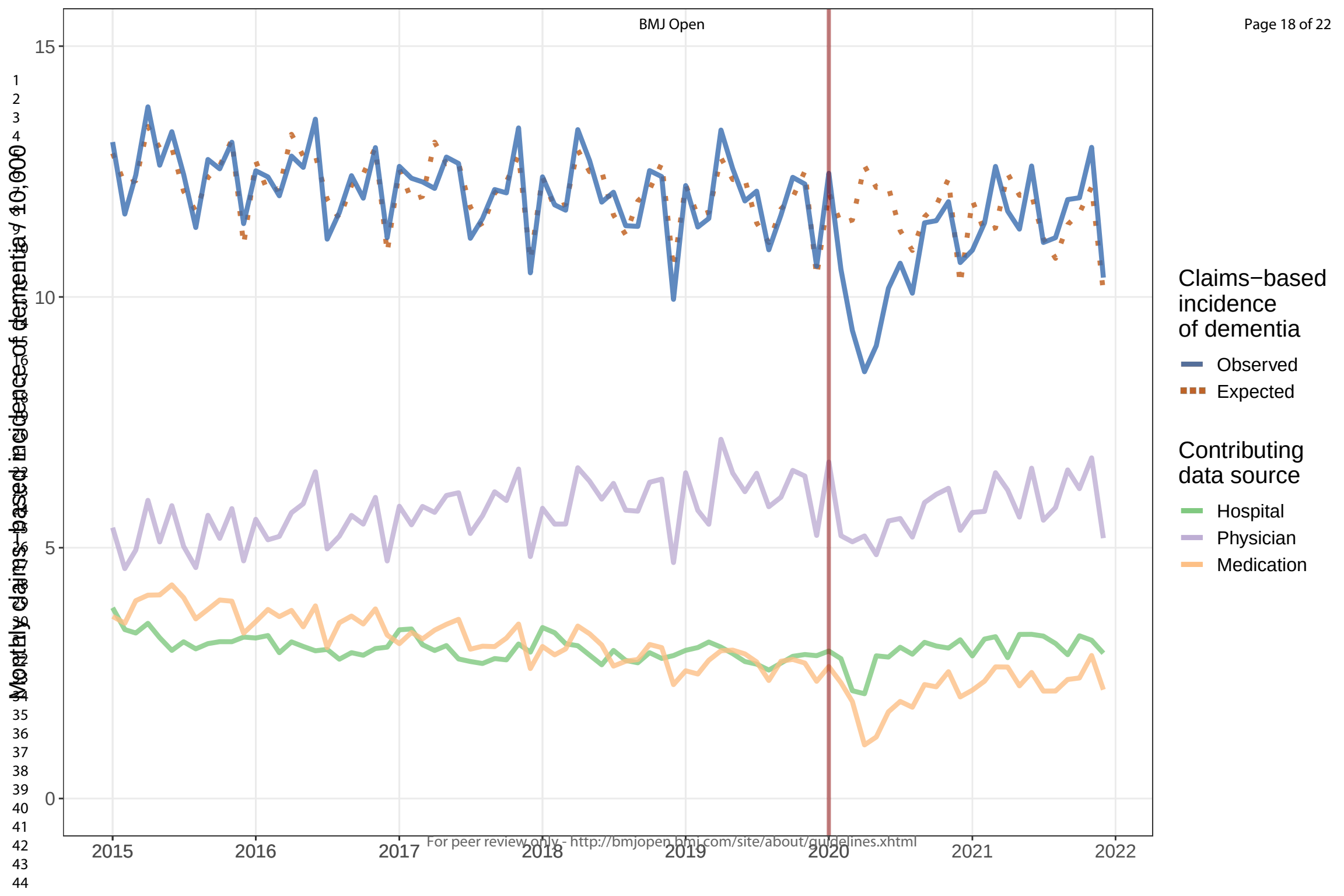
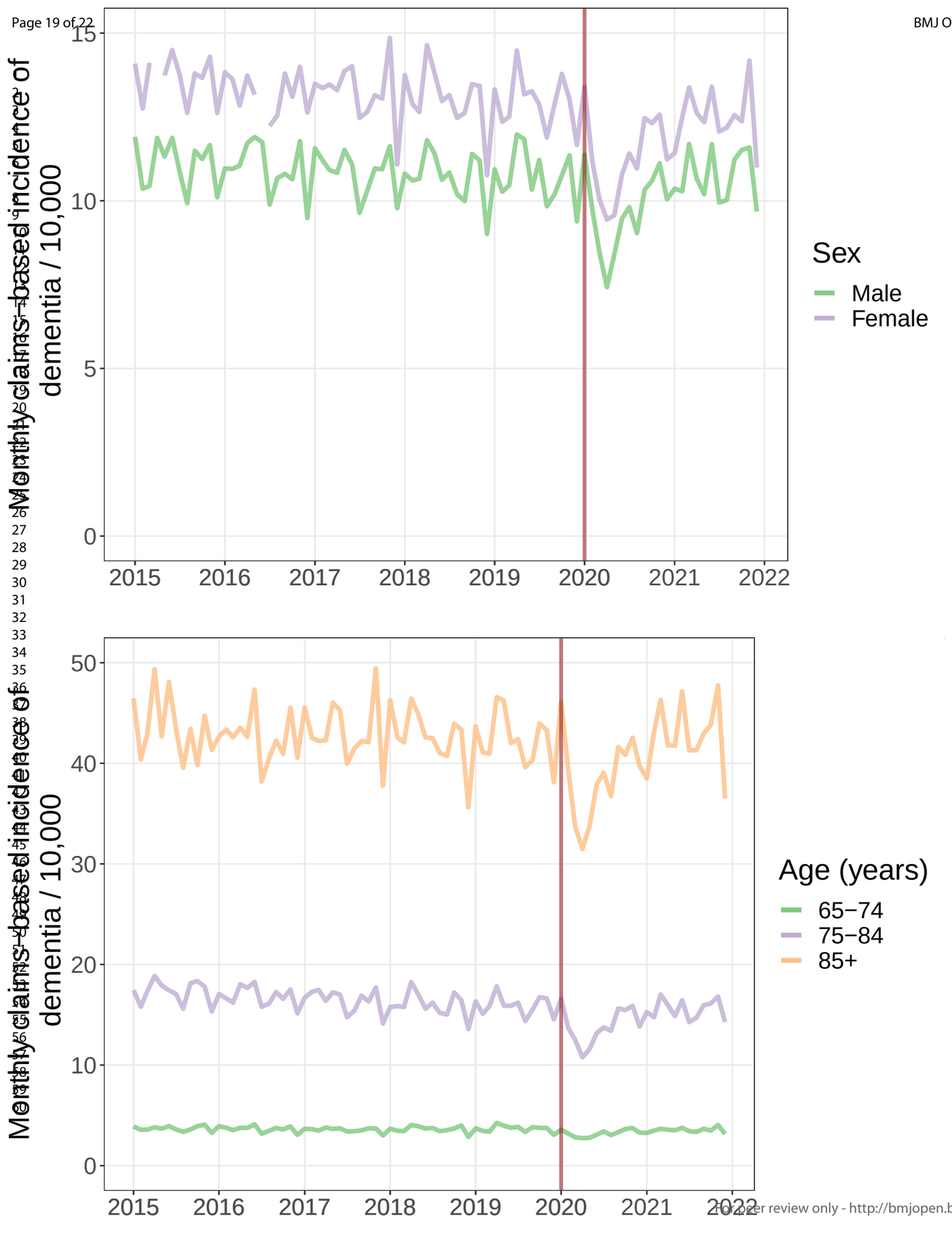
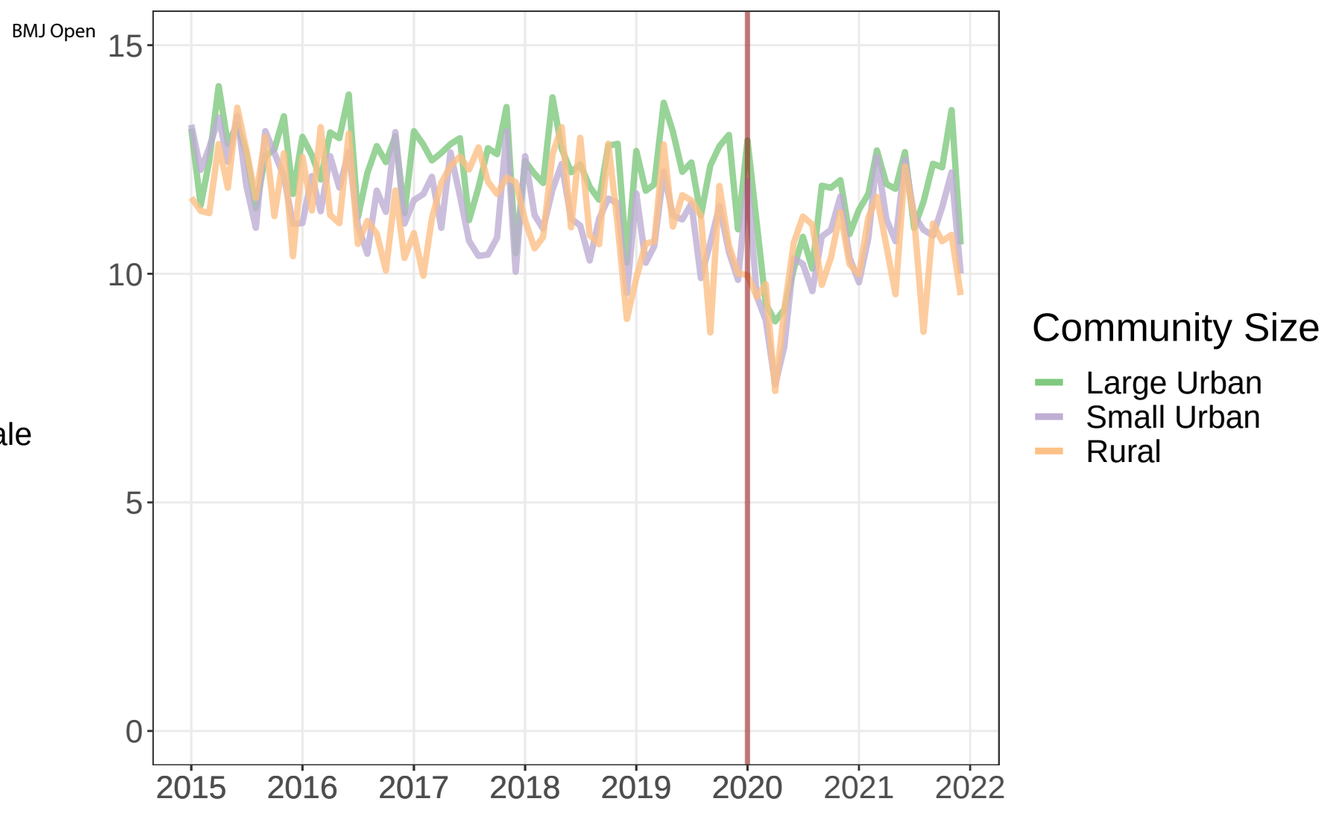
Figure Legends

Figure 1. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by data source

Figure 2. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by sex, age, and community size.







eTable 1: ICD-10-ca codes and drug identification numbers (DIN) used in dementia case ascertainment

ICD-10-CA	Drug Identification numbers (DIN)
G30, F00, F01, F02, F03	02232043,02232044,02242115,02242116,02242117,02242118,02244298,02244299, 02244300,02245240,02260638,02266717,02266725,02266733,02269457,02269465, 02270773,02270781,02270803,02293021,02293048,02293056,02302845,02302853, 02305984,02305992,02306018,02306026,02306034,02306042,02306050,02306069, 02307685,02307693,02307707,02307715,02308169,02308177,02308185,02308193, 02311283,02311291,02311305,02311313,02316943,02316951,02316978,02320908, 02321130,02321599,02321602,02322331,02322358,02324059,02324067,02324563, 02324571,02324598,02324601,02328666,02328682,02332809,02332817,02332825, 02332833,02333376,02333384,02333392,02336715,02336723,02336731,02336758, 02339439,02339447,02339455,02340607,02340615,02344807,02348950,02349116, 02359472,02359480,02362260,02362279,02366487,02367688,02367696,02375532, 02375729,02375737,02375745,02375753,02377950,02377969,02377977,02381508, 02381516,02382830,02392283,02392291,02392305,02395584,02395592,02397595, 02397609,02397617,02397625,02398370,02398389,02398397,02398885,02398893, 02400561,02400588,02401614,02401622,02401630,02401649,02402092,02402106, 02402645,02402653,02404419,02404427,02406985,02406993,02407000,02407019, 02408600,02408619,02409887,02409895,02412853,02412861,02412918,02412934, 02413671,02413698,02416417,02416425,02416573,02416581,02416603,02416948, 02416956,02416999,02417006,02417014,02417022,02419238,02419246,02419254, 02419866,02419874,02420597,02420600,02420821,02420848,02420856,02421364, 02421453,02421461,02425157,02425165,02425173,02425343,02425351,02425742, 02426293,02426307,02426846,02426854,02426943,02426951,02427273,02427567, 02427575,02427583,02427591,02428482,02428490,02430371,02432684,02432692, 02432803,02439557,02439565,02443015,02443023,02443031,02443082,02446049, 02446669,02446677,02447002,02447010,02383896,02383888,02386011,02386003, 02386046,02386038,02423537,02423529,02423421,02423413,02305976,02312492, 02312506,02312514,02312522,02308622,02308630,02308649,02308657,02295245, 02295229,02295237,02244302,02260611,02376334,02467453,02467461

eTable 2. Observed and expected claims-based diabetes incidence with relative and absolute differences, Jan 2020 to Dec 2021, Ontario, Canada

Month	Observed incidence	Expected incidence	Relative difference	Absolute difference in cases1,2	Cumulative difference in cases since Jan 2020	Cumulative difference in months of expected cases3
Jan-20	11.7	10.5	11%	256	256	0.10
Feb-20	11.2	10.8	3%	84	339	0.13
Mar-20	10.0	11.6	-13%	-347	-8	0.00
Apr-20	6.2	12.5	-50%	-1413	-1421	-0.56
May-20	7.0	13.0	-46%	-1348	-2769	-1.09
Jun-20	9.5	12.5	-24%	-679	-3448	-1.36
Jul-20	9.5	10.9	-13%	-310	-3758	-1.48
Aug-20	9.1	10.4	-13%	-299	-4057	-1.60
Sep-20	11.4	11.5	-1%	-38	-4094	-1.61
Oct-20	12.1	12.0	1%	33	-4062	-1.60
Nov-20	13.0	12.4	5%	154	-3907	-1.54
Dec-20	11.3	9.9	14%	326	-3581	-1.41
Jan-21	10.5	10.5	0%	-1	-3582	-1.41
Feb-21	12.2	10.8	13%	330	-3253	-1.28
Mar-21	14.9	11.5	29%	784	-2469	-0.97
Apr-21	13.2	12.4	6%	182	-2287	-0.90
May-21	13.1	12.9	1%	30	-2257	-0.89
Jun-21	15.6	12.5	25%	733	-1524	-0.60
Jul-21	12.8	10.8	18%	459	-1065	-0.42
Aug-21	12.5	10.4	20%	490	-575	-0.23
Sep-21	14.2	11.5	24%	638	63	0.02
Oct-21	14.5	11.9	22%	611	674	0.27
Nov-21	17.1	12.3	38%	1117	1791	0.71
Dec-21	13.5	9.9	37%	864	2655	1.05

1. Calculated as difference between observed and expected incidence multiplied by population at risk of dementia, rounded to whole number
2. Rounded to whole number
3. Based on monthly average of new ascertainment in 2019

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
4Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA - aggregated data
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	7, Table1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7, Tables, Figures
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Examining the immediate and on-going impact of the COVID-19 pandemic on population-based estimates of dementia: a population-based time series analysis in Ontario, Canada

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-067689.R1
Article Type:	Original research
Date Submitted by the Author:	25-Nov-2022
Complete List of Authors:	Jones, Aaron; Hamilton, Department of Health Research Methods, Evidence, and Impact; ICES Bronskill, Susan; ICES Maclagan, Laura; ICES Jaakkimainen, R. Liisa; University of Toronto, Department of Family and Community Medicine; Sunnybrook Health Sciences Centre, Department of Family and Community Medicine Kirkwood, David; ICES Mayhew, Alexandra; McMaster University, Health Research Methods, Evidence, and Impact Costa, Andrew P ; Hamilton, Department of Health Research Methods, Evidence, and Impact Griffith, Lauren; McMaster University, Clinical Epidemiology and Biostatistics
Primary Subject Heading:	Health services research
Secondary Subject Heading:	Geriatric medicine, Public health
Keywords:	COVID-19, Dementia < NEUROLOGY, Public health < INFECTIOUS DISEASES, GERIATRIC MEDICINE

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Examining the immediate and on-going impact of the COVID-19 pandemic on population-based estimates of dementia: a population-based time series analysis in Ontario, Canada

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Word count: 3,054

ABSTRACT

Objectives

Population-based chronic disease surveillance systems were likely disrupted by the COVID-19 pandemic. The objective of this study was to examine the immediate and on-going impact of COVID-19 pandemic on the claims-based incidence of dementia.

Methods

We conducted a population-based time series analysis from January 2015 to December 2021 in Ontario, Canada. We calculated the monthly claims-based incidence of dementia using a validated case ascertainment algorithm drawing from routinely-collected health administrative data. We used autoregressive linear models to compare the claims-based incidence of dementia during the COVID-19 period (2020-2021) to the expected incidence had the pandemic not occurred, controlling for seasonality and secular trends. We examined incidence by source of ascertainment and across strata of sex, age, community size, and number of health conditions.

Results

The monthly claims-based incidence of dementia dropped from a 2019 average of 11.9 per 10,000 to 8.5 per 10,000 in April 2020 (32.6% lower than expected). Incidence returned to expected levels by late 2020. Across the COVID-19 period there were a cumulative 2,990 (95% CI [2,109-3,704]) fewer cases of dementia observed than expected, equivalent to 1.05 months of new cases. Despite the overall recovery, ascertainment rates continued to be lower than expected among individuals aged 65-74 years and in large urban areas. Ascertainment rates were higher than expected in hospital and among individuals with 11 or more health conditions.

Conclusions

The claims-based incidence of dementia recovered to expected levels by late 2020, suggesting minimal long-term changes to population-based dementia surveillance. Continued monitoring of claims-based incidence is necessary to determine whether the lower than expected incidence among individuals 65-74 and in large urban areas, and higher than expected incidence among individuals with 11 or more health conditions, is transitory.

Keywords: COVID-19, dementia, administrative data, chronic disease surveillance

Strengths and Limitations

- The population-based design enables examination of the research question over a large and representative population.
- The validated case ascertainment algorithm used in the study draws on health system encounters from multiple sectors.
- However, chronic disease ascertainment dates derived from health administrative data may not align with the date of clinical diagnosis.

INTRODUCTION

Dementia case ascertainment algorithms based on health administrative data are regularly used in population-based research and chronic disease surveillance.[1–3] By tracking the incidence and prevalence of diseases over time, chronic disease surveillance systems provide critical information for public health planning and evaluation.[4] In the absence of national registries or screening programs, administrative databases are a vital source of data on the epidemiology of chronic diseases.[5] Claims-based case ascertainment methods for dementia combine information gathered from routinely-collected health records, including physician encounters, hospital admissions, and dementia-specific medication use, to identify individuals who are likely to have been diagnosed with dementia. The performance of these algorithms varies by setting and jurisdiction, but they typically achieve high positive predictive value with reasonable sensitivity.[6] While these algorithms have clear utility, there are also known challenges as the methods depend on interactions with the health system which can be used to identify dementia diagnoses.[7] Accurate ascertainment requires equitable and consistent access to health services and recording of relevant diagnoses.

The COVID-19 pandemic had a wide-ranging impact on health service use, including reductions in care volumes across settings[8], rapid uptake of virtual care[9], and changes in the most common reasons for which health care was sought.[10] Examining changes in the claims-based incidence of dementia will yield insight into the the disruptions of the pandemic on physician diagnoses of dementia. The extent and longevity of any impact of the COVID-19 pandemic on claims-based incidence of dementia has important implications for the future use of population-based dementia estimates. The objective of this study was to examine how the claims-based incidence of dementia changed across the COVID-19 period in Ontario, Canada, both immediately at the start of the pandemic, as well as over time. We examined differences in the claims-based incidence across contributing data sources (physician encounters, hospital admissions, medications) and across sociodemographic strata of age, sex, community size, and health conditions.

METHODS

Setting and Study Design

We conducted a time series analysis using population-based health administrative datasets in Ontario, Canada. Ontario has a population of approximately 15 million individuals, including more than 2 million over the age of 65 years.[11] Ontario's health system includes publicly-funded universal health insurance for medically necessary services, including physician care, hospital-based care, and medication coverage for individuals aged 65 years and older. According to Canadian guidelines[12], routine cognitive screening of asymptomatic individuals for mild cognitive impairment or dementia is not recommended, but the assessment of cognition, activities of daily living, and neuropsychiatric symptoms is indicated when there are clinically significant concerns for a cognitive disorder. In Ontario there are no incentives for clinicians to screen for dementia such as exist for certain other chronic diseases [13].

Population

Our population was an open cohort of older adults 65 years at risk of dementia. We included older adults living in both community and congregate care settings.

Dementia case ascertainment

We used the dementia case definition from the Canadian Chronic Disease Surveillance System.[14] The validated algorithm identifies individuals likely diagnosed with dementia using administrative records from physician encounters, hospital admissions, and use of dementia-specific medications. Individuals are considered to have been likely diagnosed with dementia when they meet any one of the following criteria: 1.) three separate physician encounters with a dementia ICD-9/10 code, with at least 30 days separating each encounter; 2.) a single hospital admission with a dementia ICD-9/10 code; or 3.) a single dispensation of a dementia-specific medication (i.e. cholinesterase inhibitors). The ascertainment date is identified as the earliest of the hospital admission date, the medication dispensation date, or the last date of the physician encounter sequence. In Ontario, the algorithm was found to outperform other claims-based formulations and

achieved a sensitivity of 79.3%, a specificity of 99.1%, and a positive predictive value of 80.4%.[15] A full definition of the algorithm including all ICD-9/10 codes and Anatomical Therapeutic Chemical codes is listed in Supplemental Table 1. The lookback window in the administrative data to exclude individuals with prevalent dementia from the incidence calculation extended back to 1996.

Data sources

Diagnosis codes from physician encounters and hospital admissions were extracted from the Ontario Health Insurance Plan database and the Canadian Institute for Health Information's Discharge Abstract Database, respectively. Medication use was captured from the Ontario Drug Benefit database. Ontario's insurable population was identified using the Registered Persons Database. These datasets were linked using unique encoded identifiers and analyzed at ICES. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement.

Claims-based incidence of dementia

We calculated the monthly claims-based incidence of dementia per 10,000 individuals among older adults (65+ years) in Ontario at risk of dementia between January 2015 to December 2021. The incidence was calculated as the number of new ascertainments in a month, divided by the population at risk of dementia at the start of the month, divided by the count of days in the month, multiplied by 30.

Statistical analysis

We fit autoregressive linear regression models to the monthly claims-based dementia incidence[16]. Seasonality was controlled for using an indicator variable for each month[17] and long-term trend via a linear term on the number of months since beginning of the time series. The model was fit on the pre-COVID-19 pandemic period (2015 to 2019). This model was used to generate what the expected incidence of claims-based dementia would have been during the COVID-19 period (2020-2021) had the pandemic not occurred.

We calculated relative and absolute differences between observed and expected claims-based dementia incidence. We characterized the initial decline in claims-based incidence by comparing the observed and expected incidence at the month of the lowest observed incidence in 2020. We calculated the difference between the count of observed and expected dementia case ascertainments by applying the difference between the between the observed and expected incidences to the population at risk each month. We examined cumulative differences in the count of observed and expected dementia case ascertainments within calendar years and across the entire COVID-19 period. We constructed 95% confidence intervals around the cumulative differences in case ascertainments during the COVID-19 period using a 5000-replicate block bootstrap[18] with a block size of 3 months. To facilitate comparison across strata of different sizes, we expressed the cumulative difference in case ascertainments in terms of the number of months of new ascertainments they represent based on 2019 figures.

We stratified the main analysis by data source (physician encounters, hospital admissions, medications) to identify whether certain sources were more strongly affected by the pandemic. We additionally stratified by age (65-74,75-84,85+), sex (male vs. female), community size (large urban, small urban, rural), and count of health conditions (0-5, 6-10, 11+) to explore differential effects across sociodemographic strata. Community size was defined using the Rurality Index of Ontario[19]. Health condition count was defined using the Canadian Institute for Health Information Population Health Grouper[20], which includes 226 health conditions that can be ascertained via administrative data sources. All analyses were performed using R version 4.0.3.[21]

Sensitivity analysis

To examine whether the changes in claims-based incidence were related to a shifting population composition, we repeated the main analyses using incidence rates that were standardized to the age-sex distribution of Ontario on January 2015. We also repeated the main analysis among only the community-

dwelling older adult population to examine to what degree changes were due to the disproportionate impact of the pandemic on long-term care homes.

Patient and Public Involvement

No patients were involved at the conduct of this study due to limited time and resources. We have invited patients and stakeholders to help us develop and carry out our knowledge dissemination strategy.

RESULTS

The population of the older adults at risk of dementia varied from 2,030,431 (January 2015) to 2,569,017 (December 2021). The monthly claims-based incidence of dementia declined slightly across the pre-COVID-19 period from an average of 12.5 cases per 10,000 in 2015 to 11.9 cases per 10,000 in 2019. Physician encounters were the most common source of case ascertainment across the entire time series, representing approximately 50% of new cases. Claims-based incidence dropped sharply during the first months of the COVID-19 period reaching a nadir of 8.5 per 1,000 in April 2020 (32.6% less than expected) (Table 1). By late 2020, the observed incidence had returned to the pre-pandemic expected incidence but did not appreciably rebound above expected levels (Figure 1).

Table 1. Observed and expected claims-based dementia incidence with relative and absolute differences, Jan 2020 to Dec 2021, Ontario, Canada

Month	Observed incidence	Expected incidence	Relative difference	Absolute difference in cases1,2	Cumulative difference in cases since Jan 2020	Cumulative difference in months of expected cases3
Jan-20	12.5	12.1	3%	95	95	0.03
Feb-20	10.5	11.5	-8%	-225	-130	-0.05
Mar-20	9.3	11.5	-19%	-540	-670	-0.23
Apr-20	8.5	12.6	-33%	-1012	-1682	-0.59
May-20	9.0	12.2	-26%	-781	-2463	-0.86
Jun-20	10.2	12.2	-17%	-501	-2964	-1.04
Jul-20	10.7	11.3	-6%	-162	-3125	-1.09
Aug-20	10.1	10.9	-8%	-213	-3338	-1.17
Sep-20	11.5	11.6	-1%	-30	-3369	-1.18
Oct-20	11.5	11.8	-3%	-77	-3446	-1.21

Nov-20	11.9	12.4	-4%	-114	-3560	-1.25
Dec-20	10.7	10.3	4%	110	-3450	-1.21
Jan-21	10.9	11.9	-8%	-253	-3703	-1.30
Feb-21	11.5	11.3	1%	42	-3661	-1.28
Mar-21	12.6	11.4	11%	311	-3350	-1.17
Apr-21	11.7	12.5	-6%	-191	-3541	-1.24
May-21	11.3	12.0	-6%	-174	-3714	-1.30
Jun-21	12.6	12.0	5%	148	-3567	-1.25
Jul-21	11.1	11.2	-1%	-20	-3587	-1.26
Aug-21	11.2	10.8	4%	105	-3482	-1.22
Sep-21	11.9	11.4	4%	129	-3353	-1.17
Oct-21	12.0	11.7	3%	78	-3275	-1.15
Nov-21	13.0	12.2	6%	205	-3070	-1.07
Dec-21	10.4	10.1	3%	80	-2990	-1.05
2020 Cumulative difference in cases (95%CI)					-3,450 (-3753,-3,078)	
2021 Cumulative difference in cases (95%CI)					460 (49, 957)	
2020-2021 Cumulative difference in cases (95%CI)					-2,990 (-3,704-2,109)	

1. Calculated as difference between observed and expected incidence multiplied by population at risk of dementia, rounded to whole number
2. Rounded to whole number
3. Based on monthly average of new ascertainments in 2019

Between January 2020 and December 2021, there were a cumulative 2,990 (95% CI: 2,109-3,704) fewer case ascertainments observed than expected, a gap equivalent to 1.05 months of cases based on 2019 averages. The vast majority of the fewer-than-expected ascertainments were accumulated between February 2020 and June 2020. Across 2021 as a whole, there were slightly more cases observed than expected (460 cases (95% CI: 49, 957)). In each of the final five months of the time series, the observed count exceeded the expected count by 3%-6% (Table 1).

All data sources exhibited drops in claims-based incidence during the first months of the pandemic, with medication use demonstrating the largest relative decrease (59.4%) in April 2020, compared to 26.9% for physician encounters, and 27.4% for hospital admissions (Figure 2, Table 2). After the initial decline, ascertainments in the hospital setting recovered the quickest, followed by medication use. Throughout 2021,

observed case ascertainment from physician encounters continued to lag behind expected ascertainments, while observed ascertainments in the other settings exceeded the expected number of cases.

Table 2. Changes in the claims-based dementia incidence during the COVID-19 pandemic with cumulative differences between observed and expected cases, by data source, sex, age, community size, and chronic condition count in Ontario, Canada

		Data source		
Measure	**Overall**	**Physician encounters**	**Hospital admissions**	**Medication use**
2019 Average incidence / 10,000	11.9	6.2	2.9	2.7
2020 Nadir incidence / 10,000	8.5	4.9	2.1	1.1
Percent drop in incidence at nadir vs. expected	32.6%	26.9%	27.4%	59.4%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.63 (-1.53, 1.41)	0.32 (-0.03, 0.72)	-1.78 (-2.19, -1.38)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-1.23 (-1.52, -0.94)	1.90 (1.43, 2.45)	1.51 (0.96, 2.04)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-2.86 (-3.36, -2.35)	2.23 (1.38, 3.17)	-0.27 (-1.23, 0.66)

		Sex	
Measure	**Overall**	**Male**	**Female**
2019 Average incidence / 10,000	11.9	10.7	12.9
2020 Nadir incidence / 10,000	8.5	7.4	9.4
Percent drop in incidence at nadir vs. expected	32.6%	34.6%	31.1%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.06 (-1.23, -0.88)	-1.32 (-1.47, -1.16)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	0.32 (0.10, 0.55)	0.04 (-0.16, 0.26)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-0.73 (-1.13, -0.33)	-1.28 (-1.63, -0.90)

		Age		
Measure	**Overall**	**65-74**	**76-85**	**85+**

2019 Average incidence / 10,000	11.9	3.6	15.6	48.4
2020 Nadir incidence / 10,000	8.5	2.7	10.6	36.0
Percent drop in incidence at nadir vs. expected	32.6%	30.1%	36.0%	30.0%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.39 (-1.64, -1.17)	-1.19 (-1.36, -0.99)	-1.08 (-1.28, -0.89)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.29 (-0.59, -0.02)	0.40 (0.16, 0.65)	0.16 (-0.09, 0.41)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-1.67 (-2.26, -1.16)	-0.49 (-1.20, -0.35)	-0.92 (-1.38, -0.49)
		Community size		
Measure	**Overall**	**Large Urban**	**Small Urban**	**Rural**
2019 Average incidence / 10,000	11.9	12.4	10.9	11.0
2020 Nadir incidence / 10,000	8.5	8.9	7.7	7.1
Percent drop in incidence at nadir vs. expected	32.6%	32.4%	31.0%	38.8%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.46 (-1.25, -1.54)	-0.53 (-0.24, -0.81)	-0.89 (-1.43, -0.33)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.20 (-0.36, -0.02)	0.94 (0.61, 1.30)	0.04 (-0.69, 0.77)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-1.62 (-1.90, -1.26)	0.41 (-0.20, 0.90)	-0.86 (-2.11, 0.44)
		Health Conditions		
Measure	**Overall**	**0-5**	**6-10**	**11+**
2019 Average incidence / 10,000	11.9	6.5	14.8	42.1
2020 Nadir incidence / 10,000	8.5	4.6	10.7	35.7
Percent drop in incidence at nadir vs. expected	32.6%	34.4%	30.9%	17.8%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.92 (-2.19, -1.66)	-0.50 (-0.72, -0.26)	1.00 (0.76, 1.23)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.68 (-0.35, 0.05)	1.37 (1.10, 1.66)	2.44 (2.14, 2.73)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-2.30 (-2.87, -1.60)	0.88 (0.38, 1.40)	3.44 (2.90, 3.96)

1. Cumulative difference between observed and expected cases expressed in terms of the number of months of new cases based on 2019 figures

Analysis across sociodemographic strata

Initial declines in claims-based incidence across sociodemographic strata were broadly similar, with the smallest drop at 30.0% less than expected among individuals 85+ and the largest drop at 38.8% less than expected among individuals living in rural locations (Figure 2, Table 2). Recoveries were uneven however, and ascertainments in 2021 among individuals aged 65-74 and those residing in large urban locations tracked below expected levels, while ascertainments among those in small urban locations tracked significantly higher.

Most differences were evident across strata defined by number of health conditions. The initial drop in the strata of 0-5 conditions was 34.4% compared to only 17.8% in the strata of those with 11+ conditions. Notably, while the claims-based incidence in the 0-5 condition group recovered much more slowly than the overall population, the incidence in the 11+ group exceeded the expected ascertainment counts even in 2020 and ended the 2020-2021 period with an excess of 3.44 months of ascertainments.

Sensitivity analysis

The standardized claims-based incidence rate remained similar to observed rate across the study period, drifting higher to a maximum difference of 0.18 in March of 2021 (Supplemental Table 2). Repeating the primary analysis using the standardized incidence rate yielded a cumulative difference of 1.04 (0.73, 1.30) months fewer ascertainments than expected, nearly identical to the main analysis (Supplemental Table 3). Including only the community-dwelling population reduced the average 2019 incidence per 10,000 from 12.04 to 10.32. Replicating the primary analysis resulted in a cumulative difference of 0.89 (0.57, 1.23) months fewer ascertainments than expected across the pandemic period, slightly lower than the primary analysis.

DISCUSSION

We found that the claims-based incidence of dementia in Ontario dropped sharply at the start of the COVID-19 pandemic in 2020. Claims-based incidence returned to expected levels by the end of 2020 but did not appreciably rebound above the expected levels. As a result, across the pandemic period there have been significantly fewer dementia ascertainments observed than expected. Although the overall incidence returned to normal levels, the recovery was uneven. Cases ascertained via physician encounters, among individuals 65-74 years of age, and in large urban areas have continued to lag expected counts. Cases ascertained in hospital and among individuals with 11 or more health conditions have exceeded expected counts.

The drop in the claims-based incidence of dementia in early 2020 mirrors the reductions in health service use that occurred in Ontario at the same time across multiple sectors, including outpatient physician visits, emergency department visits, and hospital admissions.[8,9,22] At the nadir in April 2020, hospitalizations and emergency department visits were approximately 50% lower than historical levels, while rates of outpatient physician services dropped by 40%. However, usage rates within all sectors returned to normal levels by the end of the 2020. The observed claims-based incidence also returned to the expected incidence along the same timeline, which broadly suggests no major long-term changes to the performance of the case ascertainment algorithms. A temporary drop in the claims-based incidence due to lockdowns, avoidance of in-person visits, and reduced access to community-based physician care may amount to a mere historical anomaly. However, the small, but enduring, ascertainment gap bears continued monitoring.

The etiology of the persistent undercount in cases is likely multifactorial in nature. Given how closely the fall and rise of the claims-based incidence follows the broader rates of health service use, one likely contributor is change in health-seeking behavior, patient access to health care services, and delivery of health services during the pandemic and recovery. This is further supported by the observation of larger impacts in the younger and healthier groups that typically use less care. Younger individuals experienced greater relative reductions in health service use during the pandemic compared to older individuals and therefore it may take more time for the ascertainment rates for younger individuals to regain their normal levels[23]. Beyond

changes in health service use, another likely contributing factor is higher relative mortality rates among individuals at higher risk of developing dementia[24]. This effect would be most noticeable among population with the high COVID-related mortality, such as residents of long-term care homes. A mortality effect likely explains the differences we observed between the overall population and community-dwelling subset.

Notably, we found that ascertainments from physician encounters lagged expected counts throughout the entire pandemic period, despite the fact that overall physician visit volumes recovered to normal levels in 2020[23]. This may be related to the rapid uptake of virtual care as the challenges of performing cognitive testing virtually may lead to fewer or delayed diagnoses of dementia as physicians adapt to new tools[25,26]. For example, comorbid sensory impairment is a contraindication for remote cognitive screening[27]. Additionally, virtual care may also be less accessible to older adults living with frailty or without a caregiver[28]. Finally, ascertainments via physician encounters are more susceptible to disruption as the algorithm requires a specific number of visits within a specific time frame. An interruption in access may break the sequence of visits and delay ascertainment. The lower than expected incidence within large urban areas is at a glance surprising as individuals within these areas typically have the greatest access to health care[29]. However, the shift to virtual visits was most pronounced in urban areas.[9] Additionally, urban areas were under strict public health measures for longer periods of time and therefore individuals in the these areas may have experienced longer delays in resuming normal health service use levels[30].

While we observed fewer than expected cases within most strata, there were two subgroups for which we observed higher incidence – hospital ascertainments and individuals with 11 or more health conditions. The increase in the ascertainments in hospital is concordant with published reports that hospital admission rates for dementia and delirium increased or held study during the pandemic even as overall hospitalization rates declined [2,31–33]. This population with 11 or more health conditions is small, approximately 7% of the older adult population without dementia, but is highly comorbid, at high risk of developing dementia, and are frequent users of the health care system[34]. The higher incidence in this population may be partially a result

of increased social isolation in those living alone and visitation restrictions in hospitals and congregate care settings. Conversely, for those living in multigenerational households, the increase in remote work during the pandemic may have afforded caregivers additional opportunity to observe cognitive or behavioral changes in older family members, leading them to seek formal evaluation. Additionally there is emerging evidence that cognitive decline, including increased risk of developing dementia, is a long-term sequalae of COVID-19 infection[35]. Further cohort studies should focus on changes in dementia incidence in this highly co-morbid population.

The unevenness of the rebound in claims-based incidence of dementia across various sociodemographic strata warrants on-going monitoring to determine whether the incidence eventually reverts to the long-term averages. Research studies that rely on claims-based dementia ascertainment to generate cohorts or define outcomes need to carefully consider the impact of the pandemic on their research. Additionally, health system policymakers should carefully consider the impact of any future public health restrictions on individuals at elevated risk of developing dementia. In particular, ensuring family members and caregivers can visit patients in hospital and long-term care homes can reduce the risk of delirium and dementia associated with increased social isolation. Also, in-person visits healthcare visits for individuals with difficulty participating in virtual consultations should be preserved to protect access to care and diagnosis. A missed or delayed diagnosis of dementia reduces the time during which the person living with dementia can maintain control of decision-making and care planning and delays the initiation of interventions that may slow cognitive decline[36,37].

Limitations

Case ascertainment via administrative data enables population-based chronic disease surveillance, but does not perfectly correspond to clinical diagnoses or necessarily represent the experience of the individual. For example, a physician may communicate a diagnosis to patient without entering it into the administrative record. In addition, the case detection via administrative requires equitable access to care and thus may

underperform among populations with impaired access. Ultimately research using case ascertainment from administrative data cannot replace traditional cohort studies to capture the patient experience of people living with dementia. Finally, differences in the severity of COVID-19 pandemic and public health system response may result in differences in how population-based dementia estimates have changed across jurisdictions.

Conclusion

Claims-based dementia incidence as estimated from routinely-collected data fell early in the COVID-19 pandemic but returned to expected levels by late 2020. However, as of the end of 2021 there were still significantly fewer cumulative dementia cases observed than expected across the pandemic period. Rates of case ascertainment were lower than expected among individuals 65-74 years old and in large urban areas even after health service use rebounded. Cases ascertained in hospital and among individuals with 11+ health conditions were higher than expected. Continued population-based monitoring of dementia incidence is necessary to identify whether these effects are transitory.

ETHICS APPROVAL STATEMENT

ICES is a prescribed entity under Ontario's Personal Health Information Protection Act (PHIPA). Section 45 of PHIPA authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects that use data collected by ICES under section 45 of PHIPA, and use no other data, are exempt from REB review. The use of the data in this project is authorized under section 45 and approved by ICES' Privacy and Legal Office.

DATA SHARING STATEMENT

The dataset from this study is held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the dataset publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at www.ices.on.ca/DAS. The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

CONTRIBUTORS

AJ, AC, and LG conceived the work. AJ developed the design and conducted all analyses. DK performed data curation. AJ wrote the initial draft. AJ,SB, LM, RLJ, DK, AM, AC, and LG contributed to the interpretation of the work and revised the work for critical intellectual content.

COMPETING INTERERSTS

None to report

FUNDING

This study received funding from the Public Health Agency of Canada (2021-HQ-000076). This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care.

DISCLAIMER

Parts of this material are based on data and information compiled and provided by the Ontario Ministry of Health. This document used data adapted from the Statistics Canada Postal Code^{OM} Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada. Parts of this material are also based on data and information compiled and provided by the Canadian Institute for Health Information. 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. We thank IQVIA Solutions Canada Inc for use of their Drug Information File.

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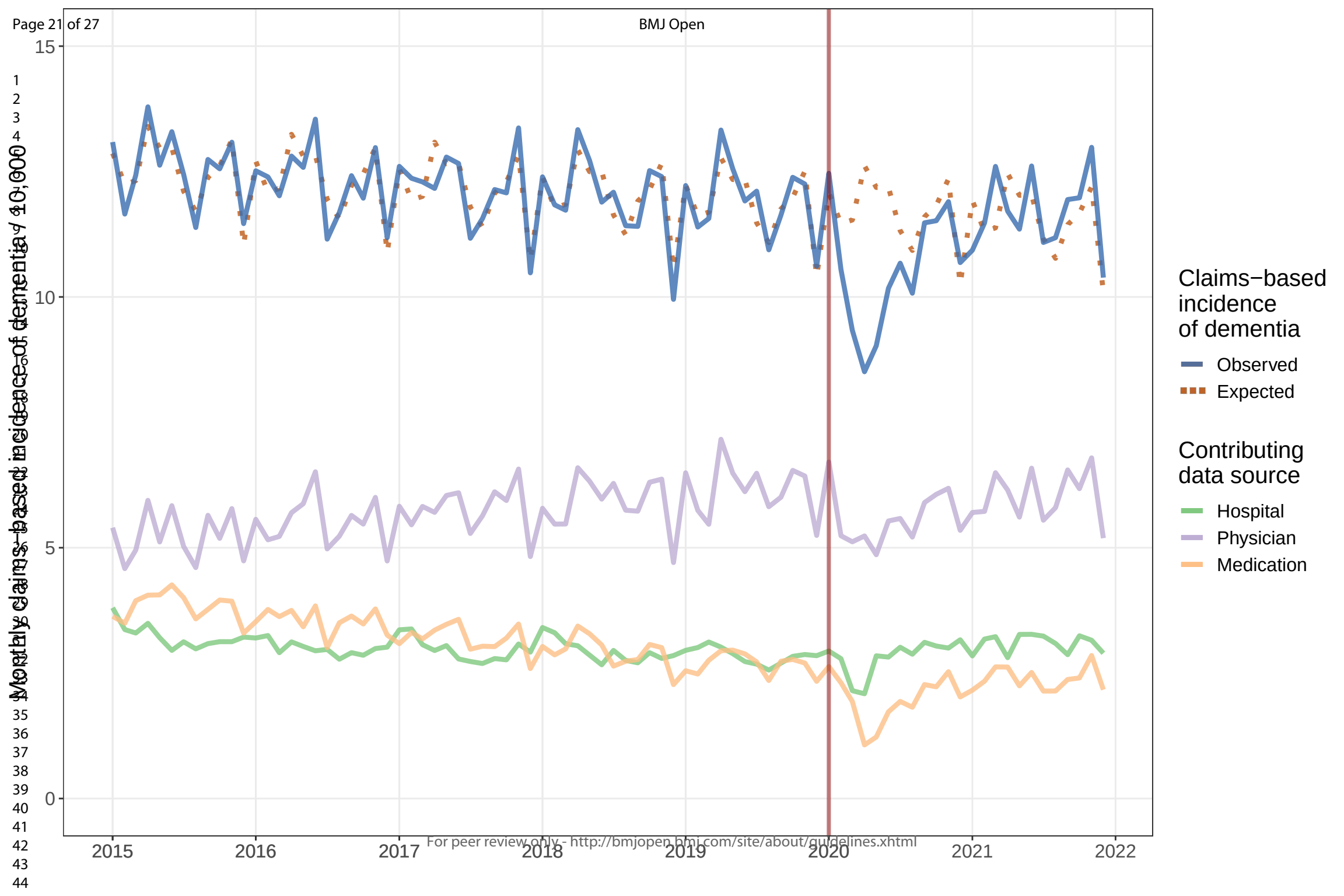
Figure Legends

Figure 1. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by data source

Figure 2. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by sex, age, and community size, and count of health conditions



Supplemental Table 1: ICD-10-ca codes and Anatomical Therapeutic Chemical (ATC) codes used in dementia case ascertainment

ICD-10-CA	ATC Codes	Generic Name
G30 (Alzheimer's disease)	N06DA02	Donepezil
F00 (Dementia in Alzheimer's disease)	N06DA03	Rivastigmine
F01 (Vascular dementia)	N06DA04	Galantamine
F02 (Dementia in other diseases classified elsewhere)	N06DX01	Memantine[1]
F03 (Unspecified dementia)		

1. Memantine is approved by Health Canada but is not included in the Ontario Drug Benefit Formulary so had no impact on this study

Supplemental Table 2. Observed and age-sex standardized claims-based dementia incidence Jan 2015 to Dec 2021, Ontario, Canada

Month	Observed incidence	Standardized incidence[1]	Difference
Jan2015	13.09	13.09	0.00
Feb2015	11.65	11.66	0.00
Mar2015	12.43	12.44	0.01
Apr2015	13.79	13.79	0.00
May2015	12.63	12.64	0.01
Jun2015	13.29	13.30	0.00
Jul2015	12.44	12.44	0.00
Aug2015	11.38	11.39	0.00
Sep2015	12.74	12.75	0.01
Oct2015	12.55	12.56	0.00
Nov2015	13.09	13.08	0.00
Dec2015	11.46	11.47	0.00
Jan2016	12.51	12.52	0.00
Feb2016	12.39	12.40	0.00
Mar2016	12.02	12.02	0.00
Apr2016	12.81	12.82	0.01
May2016	12.58	12.59	0.01
Jun2016	13.54	13.55	0.01
Jul2016	11.15	11.16	0.01
Aug2016	11.68	11.70	0.01
Sep2016	12.42	12.43	0.02
Oct2016	11.97	11.98	0.01

Nov2016	12.98	12.99	0.01
Dec2016	11.18	11.22	0.03
Jan2017	12.60	12.62	0.01
Feb2017	12.37	12.40	0.03
Mar2017	12.29	12.34	0.04
Apr2017	12.16	12.20	0.03
May2017	12.79	12.82	0.03
Jun2017	12.66	12.71	0.05
Jul2017	11.17	11.21	0.05
Aug2017	11.56	11.60	0.04
Sep2017	12.14	12.18	0.04
Oct2017	12.07	12.11	0.04
Nov2017	13.37	13.42	0.05
Dec2017	10.48	10.52	0.04
Jan2018	12.39	12.44	0.04
Feb2018	11.84	11.89	0.05
Mar2018	11.73	11.79	0.06
Apr2018	13.34	13.41	0.08
May2018	12.72	12.78	0.06
Jun2018	11.89	11.96	0.06
Jul2018	12.09	12.16	0.07
Aug2018	11.42	11.48	0.06
Sep2018	11.41	11.47	0.06
Oct2018	12.52	12.59	0.07
Nov2018	12.40	12.48	0.08
Dec2018	9.95	10.02	0.07
Jan2019	12.22	12.31	0.08
Feb2019	11.39	11.48	0.09
Mar2019	11.56	11.65	0.09
Apr2019	13.33	13.43	0.11
May2019	12.56	12.63	0.07
Jun2019	11.91	12.02	0.11
Jul2019	12.11	12.20	0.09
Aug2019	10.94	11.03	0.09
Sep2019	11.63	11.75	0.12
Oct2019	12.38	12.50	0.12
Nov2019	12.25	12.37	0.12
Dec2019	10.61	10.74	0.13
Jan2020	12.47	12.62	0.15
Feb2020	10.55	10.66	0.12
Mar2020	9.33	9.44	0.11
Apr2020	8.51	8.62	0.11
May2020	9.03	9.13	0.10
Jun2020	10.17	10.29	0.12
Jul2020	10.67	10.79	0.12

Aug2020	10.07	10.19	0.11
Sep2020	11.48	11.62	0.14
Oct2020	11.52	11.66	0.14
Nov2020	11.90	12.05	0.15
Dec2020	10.69	10.82	0.13
Jan2021	10.92	11.06	0.14
Feb2021	11.47	11.63	0.16
Mar2021	12.60	12.78	0.18
Apr2021	11.71	11.88	0.17
May2021	11.35	11.50	0.16
Jun2021	12.61	12.78	0.17
Jul2021	11.09	11.23	0.14
Aug2021	11.18	11.30	0.13
Sep2021	11.94	12.08	0.14
Oct2021	11.97	12.10	0.13
Nov2021	12.98	13.12	0.14
Dec2021	10.40	10.50	0.10

1. Incidence standardized to the age (65-74,75-84,85+) and sex (M/F) group distribution of Ontario as of January 2015.

Supplemental Table 3. Changes in the claims-based dementia incidence during the COVID-19 pandemic with cumulative differences between observed and expected cases, overall, using standardized incidence rates, and in the community-dwelling population

Measure	Overall	Standardized Rates	Community-dwelling population
2019 Average incidence / 10,000	11.9	12.0	10.3
2020 Nadir incidence / 10,000	8.5	8.62	7.04
Percent drop in incidence at nadir vs. expected	32.6%	32.20%	35.20%
2020 Cumulative difference observed vs. expected cases (in months of new cases)	-1.21 (-1.32, -1.08)	-1.19 (-1.31, -1.06)	-1.17 (-1.31, -1.03)
2021 Cumulative difference observed vs. expected cases (in months of new cases)	0.16 (0.01, 0.32)	0.16 (0.01, 0.33)	0.28 (0.09, 0.46)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)	-1.05 (-1.31, -0.77)	-1.04 (-1.30, -0.73)	-0.89 (-1.23, -0.57)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
4Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA - aggregated data
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	7, Table1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7, Tables, Figures
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Examining the immediate and on-going impact of the COVID-19 pandemic on population-based estimates of dementia: a population-based time series analysis in Ontario, Canada

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-067689.R2
Article Type:	Original research
Date Submitted by the Author:	21-Dec-2022
Complete List of Authors:	Jones, Aaron; Hamilton, Department of Health Research Methods, Evidence, and Impact; ICES Bronskill, Susan; ICES Maclagan, Laura; ICES Jaakkimainen, R. Liisa; University of Toronto, Department of Family and Community Medicine; Sunnybrook Health Sciences Centre, Department of Family and Community Medicine Kirkwood, David; ICES Mayhew, Alexandra; McMaster University, Health Research Methods, Evidence, and Impact Costa, Andrew P ; Hamilton, Department of Health Research Methods, Evidence, and Impact Griffith, Lauren; McMaster University, Clinical Epidemiology and Biostatistics
Primary Subject Heading:	Health services research
Secondary Subject Heading:	Geriatric medicine, Public health
Keywords:	COVID-19, Dementia < NEUROLOGY, Public health < INFECTIOUS DISEASES, GERIATRIC MEDICINE

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Examining the immediate and on-going impact of the COVID-19 pandemic on population-based estimates of dementia: a population-based time series analysis in Ontario, Canada

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Word count: 3086

ABSTRACT

Objectives

Population-based chronic disease surveillance systems were likely disrupted by the COVID-19 pandemic. The objective of this study was to examine the immediate and on-going impact of COVID-19 pandemic on the claims-based incidence of dementia.

Methods

We conducted a population-based time series analysis from January 2015 to December 2021 in Ontario, Canada. We calculated the monthly claims-based incidence of dementia using a validated case ascertainment algorithm drawing from routinely-collected health administrative data. We used autoregressive linear models to compare the claims-based incidence of dementia during the COVID-19 period (2020-2021) to the expected incidence had the pandemic not occurred, controlling for seasonality and secular trends. We examined incidence by source of ascertainment and across strata of sex, age, community size, and number of health conditions.

Results

The monthly claims-based incidence of dementia dropped from a 2019 average of 11.9 per 10,000 to 8.5 per 10,000 in April 2020 (32.6% lower than expected). Incidence returned to expected levels by late 2020. Across the COVID-19 period there were a cumulative 2,990 (95% CI [2,109-3,704]) fewer cases of dementia observed than expected, equivalent to 1.05 months of new cases. Despite the overall recovery, ascertainment rates continued to be lower than expected among individuals aged 65-74 years and in large urban areas. Ascertainment rates were higher than expected in hospital and among individuals with 11 or more health conditions.

Conclusions

The claims-based incidence of dementia recovered to expected levels by late 2020, suggesting minimal long-term changes to population-based dementia surveillance. Continued monitoring of claims-based incidence is necessary to determine whether the lower than expected incidence among individuals 65-74 and in large urban areas, and higher than expected incidence among individuals with 11 or more health conditions, is transitory.

Keywords: COVID-19, dementia, administrative data, chronic disease surveillance

Strengths and Limitations

- The population-based design enables examination of the research question over a large and representative population.
- The validated case ascertainment algorithm used in the study draws on health system encounters from multiple sectors.
- However, chronic disease ascertainment dates derived from health administrative data may not align with the date of clinical diagnosis.

INTRODUCTION

Dementia case ascertainment algorithms based on health administrative data are regularly used in population-based research and chronic disease surveillance.[1–3] By tracking the incidence and prevalence of diseases over time, chronic disease surveillance systems provide critical information for public health planning and evaluation.[4] In the absence of national registries or screening programs, administrative databases are a vital source of data on the epidemiology of chronic diseases.[5] Claims-based case ascertainment methods for dementia combine information gathered from routinely-collected health records, including physician encounters, hospital admissions, and dementia-specific medication use, to identify individuals who are likely to have been diagnosed with dementia. The performance of these algorithms varies by setting and jurisdiction, but they typically achieve high positive predictive value with reasonable sensitivity.[6] While these algorithms have clear utility, there are also known challenges as the methods depend on interactions with the health system which can be used to identify dementia diagnoses.[7] Accurate ascertainment requires equitable and consistent access to health services and recording of relevant diagnoses.

The COVID-19 pandemic had a wide-ranging impact on health service use, including reductions in care volumes across settings[8], rapid uptake of virtual care[9], and changes in the most common reasons for which health care was sought.[10] Examining changes in the claims-based incidence of dementia will yield insight into the the disruptions of the pandemic on physician diagnoses of dementia. The extent and longevity of any impact of the COVID-19 pandemic on claims-based incidence of dementia has important implications for the future use of population-based dementia estimates. The objective of this study was to examine how the claims-based incidence of dementia changed across the COVID-19 period in Ontario, Canada, both immediately at the start of the pandemic, as well as over time. We examined differences in the claims-based incidence across contributing data sources (physician encounters, hospital admissions, medications) and across sociodemographic strata of age, sex, community size, and health conditions.

METHODS

Setting and Study Design

We conducted a time series analysis using population-based health administrative datasets in Ontario, Canada. Ontario has a population of approximately 15 million individuals, including more than 2 million over the age of 65 years.[11] Ontario's health system includes publicly-funded universal health insurance for medically necessary services, including physician care, hospital-based care, and medication coverage for individuals aged 65 years and older. According to Canadian guidelines[12], routine cognitive screening of asymptomatic individuals for mild cognitive impairment or dementia is not recommended, but the assessment of cognition, activities of daily living, and neuropsychiatric symptoms is indicated when there are clinically significant concerns for a cognitive disorder. In Ontario there are no incentives for clinicians to screen for dementia such as exist for certain other chronic diseases [13].

Population

Our population was an open cohort of older adults 65 years at risk of dementia. We included older adults living in both community and congregate care settings.

Dementia case ascertainment

We used the dementia case definition from the Canadian Chronic Disease Surveillance System.[14] The validated algorithm identifies individuals likely diagnosed with dementia using administrative records from physician encounters, hospital admissions, and use of dementia-specific medications. Individuals are considered to have been likely diagnosed with dementia when they meet any one of the following criteria: 1.) three separate physician encounters with a dementia ICD-9/10 code, with at least 30 days separating each encounter; 2.) a single hospital admission with a dementia ICD-9/10 code; or 3.) a single dispensation of a dementia-specific medication (i.e. cholinesterase inhibitors). The ascertainment date is identified as the earliest of the hospital admission date, the medication dispensation date, or the last date of the physician encounter sequence. In Ontario, the algorithm was found to outperform other claims-based formulations and

achieved a sensitivity of 79.3%, a specificity of 99.1%, and a positive predictive value of 80.4%.[15] A full definition of the algorithm including all ICD-9/10 codes and Anatomical Therapeutic Chemical codes is listed in Supplemental Table 1. The lookback window in the administrative data to exclude individuals with prevalent dementia from the incidence calculation extended back to 1996.

Data sources

Diagnosis codes from physician encounters and hospital admissions were extracted from the Ontario Health Insurance Plan database and the Canadian Institute for Health Information's Discharge Abstract Database, respectively. Medication use was captured from the Ontario Drug Benefit database. Ontario's insurable population was identified using the Registered Persons Database. These datasets were linked using unique encoded identifiers and analyzed at ICES. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement.

Claims-based incidence of dementia

We calculated the monthly claims-based incidence of dementia per 10,000 individuals among older adults (65+ years) in Ontario at risk of dementia between January 2015 to December 2021. The incidence was calculated as the number of new ascertainments in a month, divided by the population at risk of dementia at the start of the month, divided by the count of days in the month, multiplied by 30.

Statistical analysis

We fit autoregressive linear regression models to the monthly claims-based dementia incidence[16]. Seasonality was controlled for using an indicator variable for each month[17] and long-term trend via a linear term on the number of months since beginning of the time series. The model was fit on the pre-COVID-19 pandemic period (2015 to 2019). This model was used to generate what the expected incidence of claims-based dementia would have been during the COVID-19 period (2020-2021) had the pandemic not occurred.

We calculated relative and absolute differences between observed and expected claims-based dementia incidence. We characterized the initial decline in claims-based incidence by comparing the observed and expected incidence at the month of the lowest observed incidence in 2020. We calculated the difference between the count of observed and expected dementia case ascertainments by applying the difference between the between the observed and expected incidences to the population at risk each month. We examined cumulative differences in the count of observed and expected dementia case ascertainments within calendar years and across the entire COVID-19 period. We constructed 95% confidence intervals around the cumulative differences in case ascertainments during the COVID-19 period using a 5000-replicate block bootstrap[18] with a block size of 3 months. To facilitate comparison across strata of different sizes, we expressed the cumulative difference in case ascertainments in terms of the number of months of new ascertainments they represent based on 2019 figures.

We stratified the main analysis by data source (physician encounters, hospital admissions, medications) to identify whether certain sources were more strongly affected by the pandemic. We additionally stratified by age (65-74,75-84,85+), sex (male vs. female), community size (large urban, small urban, rural), and count of health conditions (0-5, 6-10, 11+) to explore differential effects across sociodemographic strata. Community size was defined using the Rurality Index of Ontario[19]. Health condition count was defined using the Canadian Institute for Health Information Population Health Grouper[20], which includes 226 health conditions that can be ascertained via administrative data sources. All analyses were performed using R version 4.0.3.[21]

Sensitivity analysis

To examine whether the changes in claims-based incidence were related to a shifting population composition, we repeated the main analyses using incidence rates that were standardized to the age-sex distribution of Ontario on January 2015. We also repeated the main analysis among only the community-

dwelling older adult population to examine to what degree changes were due to the disproportionate impact of the pandemic on long-term care homes.

Patient and Public Involvement

No patients were involved at the conduct of this study due to limited time and resources. We have invited patients and stakeholders to help us develop and carry out our knowledge dissemination strategy.

RESULTS

The population of the older adults at risk of dementia varied from 2,030,431 (January 2015) to 2,569,017 (December 2021). The monthly claims-based incidence of dementia declined slightly across the pre-COVID-19 period from an average of 12.5 cases per 10,000 in 2015 to 11.9 cases per 10,000 in 2019. Physician encounters were the most common source of case ascertainment across the entire time series, representing approximately 50% of new cases. Claims-based incidence dropped sharply during the first months of the COVID-19 period reaching a nadir of 8.5 per 1,000 in April 2020 (32.6% less than expected) (Table 1). By late 2020, the observed incidence had returned to the pre-pandemic expected incidence but did not appreciably rebound above expected levels (Figure 1).

Table 1. Observed and expected claims-based dementia incidence with relative and absolute differences, Jan 2020 to Dec 2021, Ontario, Canada

Month	Observed incidence	Expected incidence	Relative difference	Absolute difference in cases1,2	Cumulative difference in cases since Jan 2020	Cumulative difference in months of expected cases3
Jan-20	12.5	12.1	3%	95	95	0.03
Feb-20	10.5	11.5	-8%	-225	-130	-0.05
Mar-20	9.3	11.5	-19%	-540	-670	-0.23
Apr-20	8.5	12.6	-33%	-1012	-1682	-0.59
May-20	9.0	12.2	-26%	-781	-2463	-0.86
Jun-20	10.2	12.2	-17%	-501	-2964	-1.04
Jul-20	10.7	11.3	-6%	-162	-3125	-1.09
Aug-20	10.1	10.9	-8%	-213	-3338	-1.17
Sep-20	11.5	11.6	-1%	-30	-3369	-1.18
Oct-20	11.5	11.8	-3%	-77	-3446	-1.21

Nov-20	11.9	12.4	-4%	-114	-3560	-1.25
Dec-20	10.7	10.3	4%	110	-3450	-1.21
Jan-21	10.9	11.9	-8%	-253	-3703	-1.30
Feb-21	11.5	11.3	1%	42	-3661	-1.28
Mar-21	12.6	11.4	11%	311	-3350	-1.17
Apr-21	11.7	12.5	-6%	-191	-3541	-1.24
May-21	11.3	12.0	-6%	-174	-3714	-1.30
Jun-21	12.6	12.0	5%	148	-3567	-1.25
Jul-21	11.1	11.2	-1%	-20	-3587	-1.26
Aug-21	11.2	10.8	4%	105	-3482	-1.22
Sep-21	11.9	11.4	4%	129	-3353	-1.17
Oct-21	12.0	11.7	3%	78	-3275	-1.15
Nov-21	13.0	12.2	6%	205	-3070	-1.07
Dec-21	10.4	10.1	3%	80	-2990	-1.05
2020 Cumulative difference in cases (95%CI)					-3,450 (-3753,-3,078)	
2021 Cumulative difference in cases (95%CI)					460 (49, 957)	
2020-2021 Cumulative difference in cases (95%CI)					-2,990 (-3,704-2,109)	

1. Calculated as difference between observed and expected incidence multiplied by population at risk of dementia, rounded to whole number
2. Rounded to whole number
3. Based on monthly average of new ascertainments in 2019

Between January 2020 and December 2021, there were a cumulative 2,990 (95% CI: 2,109-3,704) fewer case ascertainments observed than expected, a gap equivalent to 1.05 months of cases based on 2019 averages. The vast majority of the fewer-than-expected ascertainments were accumulated between February 2020 and June 2020. Across 2021 as a whole, there were slightly more cases observed than expected (460 cases (95% CI: 49, 957)). In each of the final five months of the time series, the observed count exceeded the expected count by 3%-6% (Table 1).

All data sources exhibited drops in claims-based incidence during the first months of the pandemic, with medication use demonstrating the largest relative decrease (59.4%) in April 2020, compared to 26.9% for physician encounters, and 27.4% for hospital admissions (Figure 2, Table 2). After the initial decline, ascertainments in the hospital setting recovered the quickest, followed by medication use. Throughout 2021,

observed case ascertainment from physician encounters continued to lag behind expected ascertainments, while observed ascertainments in the other settings exceeded the expected number of cases.

Table 2. Changes in the claims-based dementia incidence during the COVID-19 pandemic with cumulative differences between observed and expected cases, by data source, sex, age, community size, and chronic condition count in Ontario, Canada

		Data source		
Measure	**Overall**	**Physician encounters**	**Hospital admissions**	**Medication use**
2019 Average incidence / 10,000	11.9	6.2	2.9	2.7
2020 Nadir incidence / 10,000	8.5	4.9	2.1	1.1
Percent drop in incidence at nadir vs. expected	32.6%	26.9%	27.4%	59.4%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.63 (-1.53, 1.41)	0.32 (-0.03, 0.72)	-1.78 (-2.19, -1.38)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-1.23 (-1.52, -0.94)	1.90 (1.43, 2.45)	1.51 (0.96, 2.04)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-2.86 (-3.36, -2.35)	2.23 (1.38, 3.17)	-0.27 (-1.23, 0.66)

		Sex	
Measure	**Overall**	**Male**	**Female**
2019 Average incidence / 10,000	11.9	10.7	12.9
2020 Nadir incidence / 10,000	8.5	7.4	9.4
Percent drop in incidence at nadir vs. expected	32.6%	34.6%	31.1%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.06 (-1.23, -0.88)	-1.32 (-1.47, -1.16)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	0.32 (0.10, 0.55)	0.04 (-0.16, 0.26)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-0.73 (-1.13, -0.33)	-1.28 (-1.63, -0.90)

		Age		
Measure	**Overall**	**65-74**	**76-85**	**85+**

2019 Average incidence / 10,000	11.9	3.6	15.6	48.4
2020 Nadir incidence / 10,000	8.5	2.7	10.6	36.0
Percent drop in incidence at nadir vs. expected	32.6%	30.1%	36.0%	30.0%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.39 (-1.64, -1.17)	-1.19 (-1.36, -0.99)	-1.08 (-1.28, -0.89)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.29 (-0.59, -0.02)	0.40 (0.16, 0.65)	0.16 (-0.09, 0.41)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-1.67 (-2.26, -1.16)	-0.49 (-1.20, -0.35)	-0.92 (-1.38, -0.49)
		Community size		
Measure	**Overall**	**Large Urban**	**Small Urban**	**Rural**
2019 Average incidence / 10,000	11.9	12.4	10.9	11.0
2020 Nadir incidence / 10,000	8.5	8.9	7.7	7.1
Percent drop in incidence at nadir vs. expected	32.6%	32.4%	31.0%	38.8%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.46 (-1.25, -1.54)	-0.53 (-0.24, -0.81)	-0.89 (-1.43, -0.33)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.20 (-0.36, -0.02)	0.94 (0.61, 1.30)	0.04 (-0.69, 0.77)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-1.62 (-1.90, -1.26)	0.41 (-0.20, 0.90)	-0.86 (-2.11, 0.44)
		Health Conditions		
Measure	**Overall**	**0-5**	**6-10**	**11+**
2019 Average incidence / 10,000	11.9	6.5	14.8	42.1
2020 Nadir incidence / 10,000	8.5	4.6	10.7	35.7
Percent drop in incidence at nadir vs. expected	32.6%	34.4%	30.9%	17.8%
2020 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.21 (-1.32, -1.08)	-1.92 (-2.19, -1.66)	-0.50 (-0.72, -0.26)	1.00 (0.76, 1.23)
2021 Cumulative difference observed vs. expected cases (in months of new cases)1	0.16 (0.01, 0.32)	-0.68 (-0.35, 0.05)	1.37 (1.10, 1.66)	2.44 (2.14, 2.73)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)1	-1.05 (-1.31, -0.77)	-2.30 (-2.87, -1.60)	0.88 (0.38, 1.40)	3.44 (2.90, 3.96)

1. Cumulative difference between observed and expected cases expressed in terms of the number of months of new cases based on 2019 figures

Analysis across sociodemographic strata

Initial declines in claims-based incidence across sociodemographic strata were broadly similar, with the smallest drop at 30.0% less than expected among individuals 85+ and the largest drop at 38.8% less than expected among individuals living in rural locations (Figure 2, Table 2). Recoveries were uneven however, and ascertainments in 2021 among individuals aged 65-74 and those residing in large urban locations tracked below expected levels, while ascertainments among those in small urban locations tracked significantly higher.

Most differences were evident across strata defined by number of health conditions. The initial drop in the strata of 0-5 conditions was 34.4% compared to only 17.8% in the strata of those with 11+ conditions. Notably, while the claims-based incidence in the 0-5 condition group recovered much more slowly than the overall population, the incidence in the 11+ group exceeded the expected ascertainment counts even in 2020 and ended the 2020-2021 period with an excess of 3.44 months of ascertainments.

Sensitivity analysis

The standardized claims-based incidence rate remained similar to observed rate across the study period, drifting higher to a maximum difference of 0.18 in March of 2021 (Supplemental Table 2). Repeating the primary analysis using the standardized incidence rate yielded a cumulative difference of 1.04 (0.73, 1.30) months fewer ascertainments than expected, nearly identical to the main analysis (Supplemental Table 3). Including only the community-dwelling population reduced the average 2019 incidence per 10,000 from 12.04 to 10.32. Replicating the primary analysis resulted in a cumulative difference of 0.89 (0.57, 1.23) months fewer ascertainments than expected across the pandemic period, slightly lower than the primary analysis.

DISCUSSION

We found that the claims-based incidence of dementia in Ontario dropped sharply at the start of the COVID-19 pandemic in 2020. Claims-based incidence returned to expected levels by the end of 2020 but did not appreciably rebound above the expected levels. As a result, across the pandemic period there have been significantly fewer dementia ascertainments observed than expected. Although the overall incidence returned to normal levels, the recovery was uneven. Cases ascertained via physician encounters, among individuals 65-74 years of age, and in large urban areas have continued to lag expected counts. Cases ascertained in hospital and among individuals with 11 or more health conditions have exceeded expected counts.

The drop in the claims-based incidence of dementia in early 2020 mirrors the reductions in health service use that occurred in Ontario at the same time across multiple sectors, including outpatient physician visits, emergency department visits, and hospital admissions.[8,9,22] At the nadir in April 2020, hospitalizations and emergency department visits were approximately 50% lower than historical levels, while rates of outpatient physician services dropped by 40%. However, usage rates within all sectors returned to normal levels by the end of the 2020. The observed claims-based incidence also returned to the expected incidence along the same timeline, which broadly suggests no major long-term changes to the performance of the case ascertainment algorithms. A temporary drop in the claims-based incidence due to lockdowns, avoidance of in-person visits, and reduced access to community-based physician care may amount to a mere historical anomaly. However, the small, but enduring, ascertainment gap bears continued monitoring.

The etiology of the persistent undercount in cases is likely multifactorial in nature. Given how closely the fall and rise of the claims-based incidence follows the broader rates of health service use, one likely contributor is change in health-seeking behavior, patient access to health care services, and delivery of health services during the pandemic and recovery. This is further supported by the observation of larger impacts in the younger and healthier groups that typically use less care. Younger individuals experienced greater relative reductions in health service use during the pandemic compared to older individuals and therefore it may take more time for the ascertainment rates for younger individuals to regain their normal levels[23]. Beyond

changes in health service use, another likely contributing factor is higher relative mortality rates among individuals at higher risk of developing dementia[24]. This effect would be most noticeable among population with the high COVID-related mortality, such as residents of long-term care homes. A mortality effect likely explains the differences we observed between the overall population and community-dwelling subset.

Notably, we found that ascertainments from physician encounters lagged expected counts throughout the entire pandemic period, despite the fact that overall physician visit volumes recovered to normal levels in 2020[23]. This may be related to the rapid uptake of virtual care as the challenges of performing cognitive testing virtually may lead to fewer or delayed diagnoses of dementia as physicians adapt to new tools[25,26]. For example, comorbid sensory impairment is a contraindication for remote cognitive screening[27]. Additionally, virtual care may also be less accessible to older adults living with frailty or without a caregiver[28]. Finally, ascertainments via physician encounters are more susceptible to disruption as the algorithm requires a specific number of visits within a specific time frame. An interruption in access may break the sequence of visits and delay ascertainment. The lower than expected incidence within large urban areas is at a glance surprising as individuals within these areas typically have the greatest access to health care[29]. However, the shift to virtual visits was most pronounced in urban areas.[9] Additionally, urban areas were under strict public health measures for longer periods of time and therefore individuals in the these areas may have experienced longer delays in resuming normal health service use levels[30].

While we observed fewer than expected cases within most strata, there were two subgroups for which we observed higher incidence – hospital ascertainments and individuals with 11 or more health conditions. The increase in the ascertainments in hospital is concordant with published reports that hospital admission rates for dementia and delirium increased or held study during the pandemic even as overall hospitalization rates declined [2,31–33]. This population with 11 or more health conditions is small, approximately 7% of the older adult population without dementia, but is highly comorbid, at high risk of developing dementia, and are frequent users of the health care system[34]. The higher incidence in this population may be partially a result

of increased social isolation in those living alone and visitation restrictions in hospitals and congregate care settings. Conversely, for those living in multigenerational households, the increase in remote work during the pandemic may have afforded caregivers additional opportunity to observe cognitive or behavioral changes in older family members, leading them to seek formal evaluation. Additionally there is emerging evidence that cognitive decline, including increased risk of developing dementia, is a long-term sequalae of COVID-19 infection[35]. Further cohort studies should focus on changes in dementia incidence in this highly co-morbid population.

The unevenness of the rebound in claims-based incidence of dementia across various sociodemographic strata warrants on-going monitoring to determine whether the incidence eventually reverts to the long-term averages. Research studies that rely on claims-based dementia ascertainment to generate cohorts or define outcomes need to carefully consider the impact of the pandemic on their research. Additionally, health system policymakers should carefully consider the impact of any future public health restrictions on individuals at elevated risk of developing dementia. In particular, ensuring family members and caregivers can visit patients in hospital and long-term care homes can reduce the risk of delirium and dementia associated with increased social isolation. Also, in-person visits healthcare visits for individuals with difficulty participating in virtual consultations should be preserved to protect access to care and diagnosis. A missed or delayed diagnosis of dementia reduces the time during which the person living with dementia can maintain control of decision-making and care planning and delays the initiation of interventions that may slow cognitive decline[36,37].

Limitations

Case ascertainment via administrative data enables population-based chronic disease surveillance, but does not perfectly correspond to clinical diagnoses or necessarily represent the experience of the individual. For example, a physician may communicate a diagnosis to patient without entering it into the administrative record. In addition, the case detection via administrative requires equitable access to care and thus may

underperform among populations with impaired access. Ultimately research using case ascertainment from administrative data cannot replace traditional cohort studies to capture the patient experience of people living with dementia. Additionally, distinguishing delirium from dementia can be challenging, particularly in acute care setting[38]. Higher ascertainment rates in highly comorbid populations and in hospital settings may be in part due to diagnostic challenges. Finally, differences in the severity of COVID-19 pandemic and public health system response may result in differences in how population-based dementia estimates have changed across jurisdictions.

Conclusion

Claims-based dementia incidence as estimated from routinely-collected data fell early in the COVID-19 pandemic but returned to expected levels by late 2020. However, as of the end of 2021 there were still significantly fewer cumulative dementia cases observed than expected across the pandemic period. Rates of case ascertainment were lower than expected among individuals 65-74 years old and in large urban areas even after health service use rebounded. Cases ascertained in hospital and among individuals with 11+ health conditions were higher than expected. Continued population-based monitoring of dementia incidence is necessary to identify whether these effects are transitory.

ETHICS APPROVAL STATEMENT

ICES is a prescribed entity under Ontario's Personal Health Information Protection Act (PHIPA). Section 45 of PHIPA authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects that use data collected by ICES under section 45 of PHIPA, and use no other data, are exempt from REB review. The use of the data in this project is authorized under section 45 and approved by ICES' Privacy and Legal Office.

DATA SHARING STATEMENT

The dataset from this study is held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the dataset publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at www.ices.on.ca/DAS. The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

CONTRIBUTORS

AJ, AC, and LG conceived the work. AJ developed the design and conducted all analyses. DK performed data curation. AJ wrote the initial draft. AJ,SB, LM, RLJ, DK, AM, AC, and LG contributed to the interpretation of the work and revised the work for critical intellectual content.

COMPETING INTERERSTS

None to report

FUNDING

This study received funding from the Public Health Agency of Canada (2021-HQ-000076). This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and the Ministry of Long-Term Care.

DISCLAIMER

Parts of this material are based on data and information compiled and provided by the Ontario Ministry of Health. This document used data adapted from the Statistics Canada Postal Code^{OM} Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada. Parts of this material are also based on data and information compiled and provided by the Canadian Institute for Health Information. 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. We thank IQVIA Solutions Canada Inc for use of their Drug Information File.

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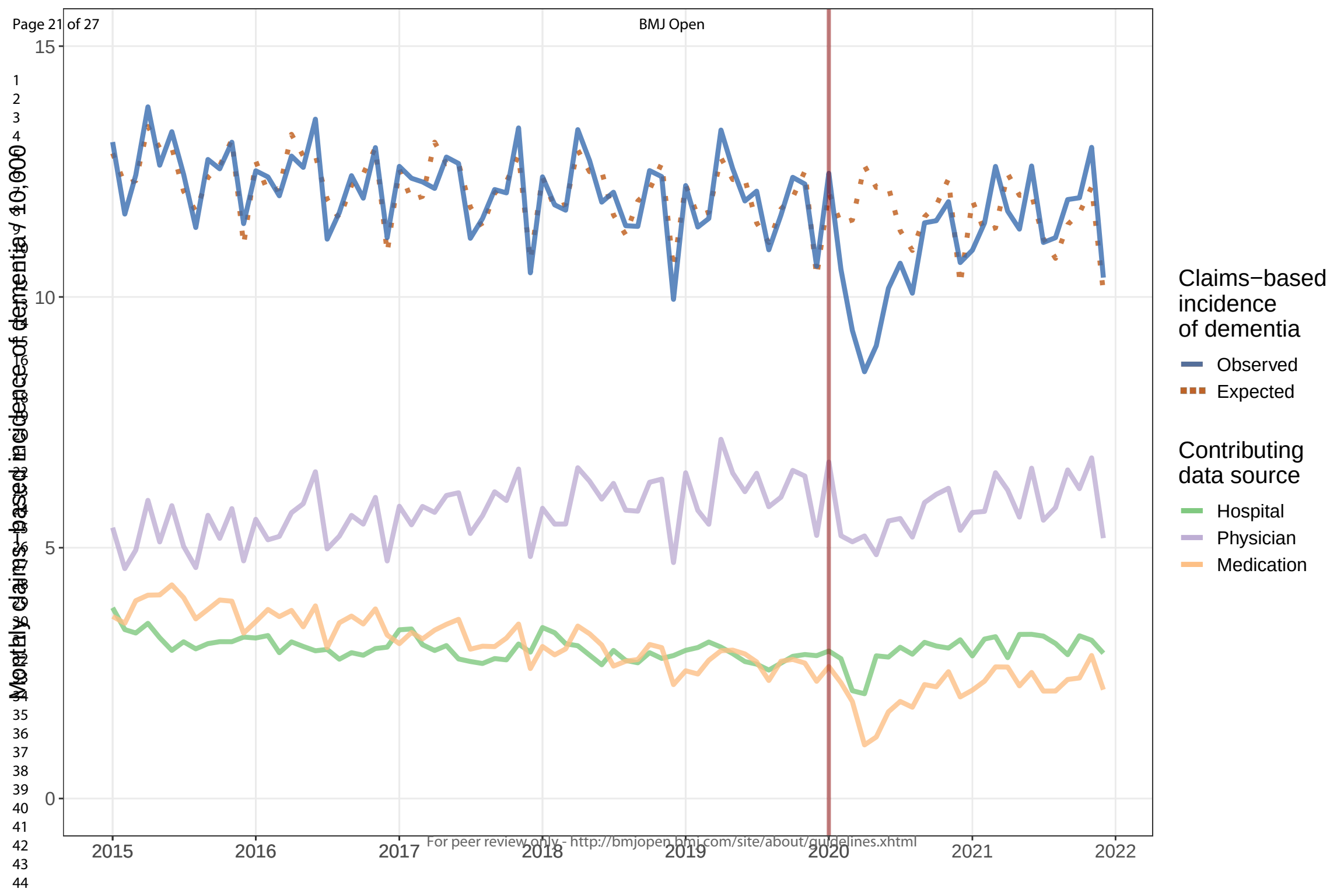
Figure Legends

Figure 1. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by data source

Figure 2. Claims-based incidence of dementia in Ontario, Canada between 2015-2021, by sex, age, and community size, and count of health conditions



Supplemental Table 1: ICD-10-ca codes and Anatomical Therapeutic Chemical (ATC) codes used in dementia case ascertainment

ICD-10-CA	ATC Codes	Generic Name
G30 (Alzheimer's disease)	N06DA02	Donepezil
F00 (Dementia in Alzheimer's disease)	N06DA03	Rivastigmine
F01 (Vascular dementia)	N06DA04	Galantamine
F02 (Dementia in other diseases classified elsewhere)	N06DX01	Memantine[1]
F03 (Unspecified dementia)		

1. Memantine is approved by Health Canada but is not included in the Ontario Drug Benefit Formulary so had no impact on this study

Supplemental Table 2. Observed and age-sex standardized claims-based dementia incidence Jan 2015 to Dec 2021, Ontario, Canada

Month	Observed incidence	Standardized incidence[1]	Difference
Jan2015	13.09	13.09	0.00
Feb2015	11.65	11.66	0.00
Mar2015	12.43	12.44	0.01
Apr2015	13.79	13.79	0.00
May2015	12.63	12.64	0.01
Jun2015	13.29	13.30	0.00
Jul2015	12.44	12.44	0.00
Aug2015	11.38	11.39	0.00
Sep2015	12.74	12.75	0.01
Oct2015	12.55	12.56	0.00
Nov2015	13.09	13.08	0.00
Dec2015	11.46	11.47	0.00
Jan2016	12.51	12.52	0.00
Feb2016	12.39	12.40	0.00
Mar2016	12.02	12.02	0.00
Apr2016	12.81	12.82	0.01
May2016	12.58	12.59	0.01
Jun2016	13.54	13.55	0.01
Jul2016	11.15	11.16	0.01
Aug2016	11.68	11.70	0.01
Sep2016	12.42	12.43	0.02
Oct2016	11.97	11.98	0.01

Nov2016	12.98	12.99	0.01
Dec2016	11.18	11.22	0.03
Jan2017	12.60	12.62	0.01
Feb2017	12.37	12.40	0.03
Mar2017	12.29	12.34	0.04
Apr2017	12.16	12.20	0.03
May2017	12.79	12.82	0.03
Jun2017	12.66	12.71	0.05
Jul2017	11.17	11.21	0.05
Aug2017	11.56	11.60	0.04
Sep2017	12.14	12.18	0.04
Oct2017	12.07	12.11	0.04
Nov2017	13.37	13.42	0.05
Dec2017	10.48	10.52	0.04
Jan2018	12.39	12.44	0.04
Feb2018	11.84	11.89	0.05
Mar2018	11.73	11.79	0.06
Apr2018	13.34	13.41	0.08
May2018	12.72	12.78	0.06
Jun2018	11.89	11.96	0.06
Jul2018	12.09	12.16	0.07
Aug2018	11.42	11.48	0.06
Sep2018	11.41	11.47	0.06
Oct2018	12.52	12.59	0.07
Nov2018	12.40	12.48	0.08
Dec2018	9.95	10.02	0.07
Jan2019	12.22	12.31	0.08
Feb2019	11.39	11.48	0.09
Mar2019	11.56	11.65	0.09
Apr2019	13.33	13.43	0.11
May2019	12.56	12.63	0.07
Jun2019	11.91	12.02	0.11
Jul2019	12.11	12.20	0.09
Aug2019	10.94	11.03	0.09
Sep2019	11.63	11.75	0.12
Oct2019	12.38	12.50	0.12
Nov2019	12.25	12.37	0.12
Dec2019	10.61	10.74	0.13
Jan2020	12.47	12.62	0.15
Feb2020	10.55	10.66	0.12
Mar2020	9.33	9.44	0.11
Apr2020	8.51	8.62	0.11
May2020	9.03	9.13	0.10
Jun2020	10.17	10.29	0.12
Jul2020	10.67	10.79	0.12

Aug2020	10.07	10.19	0.11
Sep2020	11.48	11.62	0.14
Oct2020	11.52	11.66	0.14
Nov2020	11.90	12.05	0.15
Dec2020	10.69	10.82	0.13
Jan2021	10.92	11.06	0.14
Feb2021	11.47	11.63	0.16
Mar2021	12.60	12.78	0.18
Apr2021	11.71	11.88	0.17
May2021	11.35	11.50	0.16
Jun2021	12.61	12.78	0.17
Jul2021	11.09	11.23	0.14
Aug2021	11.18	11.30	0.13
Sep2021	11.94	12.08	0.14
Oct2021	11.97	12.10	0.13
Nov2021	12.98	13.12	0.14
Dec2021	10.40	10.50	0.10

1. Incidence standardized to the age (65-74,75-84,85+) and sex (M/F) group distribution of Ontario as of January 2015.

Supplemental Table 3. Changes in the claims-based dementia incidence during the COVID-19 pandemic with cumulative differences between observed and expected cases, overall, using standardized incidence rates, and in the community-dwelling population

Measure	Overall	Standardized Rates	Community-dwelling population
2019 Average incidence / 10,000	11.9	12.0	10.3
2020 Nadir incidence / 10,000	8.5	8.62	7.04
Percent drop in incidence at nadir vs. expected	32.6%	32.20%	35.20%
2020 Cumulative difference observed vs. expected cases (in months of new cases)	-1.21 (-1.32, -1.08)	-1.19 (-1.31, -1.06)	-1.17 (-1.31, -1.03)
2021 Cumulative difference observed vs. expected cases (in months of new cases)	0.16 (0.01, 0.32)	0.16 (0.01, 0.33)	0.28 (0.09, 0.46)
2020-2021 Cumulative difference observed vs. expected cases (in months of new cases)	-1.05 (-1.31, -0.77)	-1.04 (-1.30, -0.73)	-0.89 (-1.23, -0.57)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
4Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5,6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	NA - aggregated data
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	7, Table1

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7, Tables, Figures
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.