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MAJOR ARTICLE

Neighborhood-Level Burden of Social Risk Factors on Respiratory Syncytial Virus Hospitalization in Ontario, Canada, 2016–2019

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Background. Beyond clinical risk factors, little is known about the impact of social determinants on respiratory syncytial virus (RSV) burden. Our study aimed to estimate RSV-related hospitalization rates across sociodemographic and housing characteristics.

Methods. We conducted a population-based study of all RSV-related hospitalizations in Ontario, Canada, between September 1, 2016, and August 31, 2019, using validated hospital discharge codes and census data. Crude and age-standardized annualized RSV incidence rates and rate ratios (RRs) were estimated for a range of individual-level demographics and neighborhood-level measures of marginalization and housing characteristics.

Results. Overall, the annual RSV-related hospitalization rate was 27 per 100 000, with the highest rates observed in children age <12 months (1049 per 100 000) and 12–23 months (294 per 100 000) and adults age ≥85 years (155 per 100 000). Higher RSV-related hospitalization rates were associated with increasing marginalization quintile (Q) of material resources (RR, 1.4; Q5: 33 per 100 000 vs Q1: 24 per 100 000) and household instability (RR, 1.5; Q5: 31 per 100 000 vs Q1: 22 per 100 000).

Conclusions. The burden of RSV-related hospitalization was greatest in young children and older adults, with variation by sociodemographic and housing factors. Understanding the role of these social factors is crucial for informing equitable preventive program delivery.

Keywords. hospitalization; respiratory syncytial virus; social determinants of health; socioeconomic status; housing characteristics.

Respiratory syncytial virus (RSV) is a leading cause of lower respiratory tract infection among young children, older adults, and immunocompromised individuals [1]. RSV infection represents a large burden on the health care system on a global scale, including within Canada, contributing to ∼24.8 million acute respiratory infection episodes and 76 600 deaths globally each year [1–3]. Substantial progress has been made in the field of RSV vaccines and immunoprophylaxis, which will help mitigate RSV-related hospitalization and the burden on the health care system; however, ensuring equitable access and widespread uptake of these products across population groups will be crucial for their success. This dynamic landscape, coupled with the emergence of RSV vaccines and new monoclonal antibodies for different age groups, underscores the importance of reliable RSV-related hospitalization estimates to support health system preparedness and cost-effective delivery of targeted interventions [4]. Little is known about the baseline risk in groups with high RSV burden, especially in the Canadian context.

While clinical risk factors for severe RSV disease are well recognized, it is crucial to understand the role that social and environmental variables play in severe RSV disease burden. Social factors are major determinants of morbidity and mortality, yielding distinct differences in inpatient medical services. In the context of infectious diseases, the coronavirus disease 2019 (COVID-19) pandemic further emphasized the importance of understanding the interplay between infectious diseases and social determinants of health, at both individual and neighborhood levels [5–8]. Social and structural inequities can contribute to unjust differences in how individuals are affected by RSV, such as susceptibility, contact patterns, adoption of preventive measures, and access to quality treatment [6].

Despite the variable dynamics in the timing and magnitude of RSV epidemics across communities, little is known about the differential burdens of RSV-related hospitalizations by socioeconomic status [9]. Experiences of RSV may vary by region due

Received 27 March 2024; editorial decision 01 July 2024; accepted 08 July 2024; published online 10 July 2024

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https://doi.org/10.1093/ofid/ofae384

to shared socioeconomic characteristics among community members [10]. Additionally, cohort studies of RSV infection have revealed that the social structuring and size of households play an important role in RSV transmission dynamics, in terms of characterizing contact patterns within households [11–13]. Moreover, there is a lack of comprehensive investigation into the social risk factors associated with RSV-related hospitalizations across the age spectrum beyond infancy [14, 15]. As such, the purpose of our study was to provide age-specific estimates of RSV-related hospitalization in Ontario, Canada, with a focus on understanding trends by individual-level demographics and neighborhood-level sociodemographic and housing characteristics.

METHODS

Study Population

We examined individuals in Ontario, Canada, with an eligible RSV-related hospitalization from September 1, 2016, to August 31, 2019. An RSV season was defined as September 1 to August 31 of the following year. Of 277 852 hospital admittances for acute respiratory infections from September 1, 2016, to August 31, 2019, 11 746 hospitalizations (4.2%) had an RSV-coded diagnosis. We excluded patients without a recorded provincial health insurance number, benefiting from Canada's universal health care coverage of basic medical and emergency services, resulting in 11 655 hospitalizations (4.2%). After accounting for acute hospital transfers, there was a total of 11 311 hospitalizations (4.1%). If repeated RSV-related hospitalizations occurred within 30 days of one another and between seasons, subsequent admissions were excluded from the study to prevent the same infection from being captured more than once, resulting in 11 305 hospitalizations (4.1%). For individuals with >1 RSV-related hospitalization in a given season, we included the earliest hospitalization for each season after accounting for any readmissions, as previously described [16, 17]. A total of 11 039 RSV-related hospitalizations (4.0%) were included in the study. Further inclusion and exclusion criteria are described in Supplementary Figure 1.

Data Source

Information on all inpatient RSV-related hospitalizations and their demographics was obtained from the Canadian Institute of Health Information Discharge Abstract Database. Neighborhood-level sociodemographic and housing characteristics were obtained from the 2016 Canadian census provided by Statistics Canada and the 2016 census-based Ontario Marginalization (ON-Marg) index. The 2016 Canadian census age structure was used to conduct age standardization.

Outcomes

RSV-related hospitalizations were defined as a hospitalization with at least 1 RSV-related International Classification of Diseases, 10th Revision, Canada (ICD-10-CA) code in any of the diagnosis fields: RSV pneumonia (J12.1), acute bronchitis due to RSV (J20.5), acute bronchiolitis due to RSV (J21.0), and RSV as the cause of disease classified elsewhere (B97.4). Prior validation studies have shown these codes to have extremely high specificity (>99%) for identifying RSV-related admissions in both pediatric and adult populations in Ontario, Canada, compared with laboratory-confirmed admissions, with sensitivity estimates ranging from moderate (69%) to high (>99%) in the general and pediatric populations, respectively [18, 19]. We also examined intensive care unit (ICU) admissions, in-hospital deaths, and their associated median lengths of stay. Length of stay was calculated using the earliest admission date and latest discharge date, including inpatient transfers. Additionally, we examined RSV as the most responsible diagnosis, which is the diagnosis responsible for the patient's greatest length of stay or resource utilization [20]. If inpatient transfers occurred, the earliest most responsible diagnosis in the first transfer was considered.

Individual- and Neighborhood-Level Exposures

Individual-level factors examined included age at the time of admission, sex, and month of hospital admission. Neighborhood-level housing characteristics were assessed using census data at the dissemination area (DA) level, Canada's smallest census area unit of 400 to 700 persons [21]. These characteristics included multigenerational families, household crowding, average dwelling size, and households with persons under 5 years old. Multigenerational households represented households with at least 1 person who is both a child and a grandchild within the same household [22]. Household crowding was defined as having >1 person per room in a private dwelling [23]. Unsuitable housing referred to having fewer bedrooms for the size and composition of the household, according to the National Occupancy Standard [24]. Ontario's 34 public health units were grouped into 7 aggregated public health regions [25]. Rurality was defined using the postal code Forward Sortation Area [26].

We also assessed census-based constructs included in the 2016 ON-Marg index, which measures area-level marginalization across 4 dimensions: racialized and newcomer populations, material resources, households and dwellings, and age and labor force [21, 27]. The racialized and newcomer populations dimension measured the proportion of recent immigrants and visible minorities living within an area. Lack of material resources represented poverty and the inability to purchase basic material needs. The households and dwellings dimension was related to residential characteristics and certain familial structure characteristics that have not been previously mentioned such as residential mobility, ownership, and occupancy. Age and labor force captured age structure characteristics and the proportion of labor force participation [21, 27].

Table 1. Characteristics of Patients Hospitalized for an RSV-Related Illness in Ontario From September 1, 2016, to August 31, 2019

Characteristics, No. (%)	Individuals Admitted With Any RSV-Related Illness (n = 11 039)
Demographic	…
Age	…
<12 mo	4252 (38.5)
12–23 mo	1200 (10.9)
2–4 y	959 (8.7)
5–17 y	260 (2.4)
18–49 y	250 (2.3)
50–64 y	638 (5.8)
≥65 y	3480 (31.5)
65–74 y	908 (8.2)
75–84 y	1172 (10.6)
≥85 y	1400 (12.7)
Sex	…
Female	5580 (50.6)
Male	5459 (49.5)
Season	…
2016–2017	3443 (31.2)
2017–2018	3379 (30.6)
2018–2019	4217 (38.2)
Month	…
September	56 (0.5)
October	171 (1.6)
November	838 (7.6)
December	2814 (25.5)
January	3376 (30.6)
February	1962 (17.8)
March	1099 (10.0)
April	481 (4.4)
May	146 (1.3)
June	43 (0.4)
July	23 (0.2)
August	30 (0.3)
Sociodemographic	…
Racialized and newcomer populations quintile (ON-Marg)	…
Q1 (least marginalized)	1617 (14.7)
Q2	1905 (17.3)
Q3	2093 (19.0)
Q4	2354 (21.3)
Q5 (most marginalized)	2868 (26.0)
Missing	202 (1.8)
Material resources quintile (ON-Marg)	…
Q1 (least marginalized)	2169 (19.7)
Q2	2018 (18.3)
Q3	1905 (17.3)
Q4	2128 (19.3)
Q5 (most marginalized)	2617 (23.7)
Missing	202 (1.8)
Households and dwellings quintile (ON-Marg)	…
Q1 (least marginalized)	1850 (16.8)
Q2	1933 (17.5)
Q3	1928 (17.5)
Q4	2173 (19.7)
Q5 (most marginalized)	2953 (26.8)
Missing	202 (1.8)
Age and labor quintile (ON-Marg)	…
Q1 (least marginalized)	2682 (24.3)
Q2	2134 (19.3)
Q3	1901 (17.2)
Q4	1820 (16.5)
Q5 (most marginalized)	2300 (20.8)
Missing	202 (1.8)
Housing	…
Multigenerational families quintile	…
Q1 (fewest)	2345 (21.2)
Q2	1744 (15.8)
Q3	2263 (20.5)
Q4	2332 (21.1)
Q5 (largest)	2200 (19.9)
Missing	155 (1.4)
Unsuitable housing quartile[a]	…
Q1 (fewest)	3175 (28.8)
Q2	1793 (16.2)
Q3	2745 (24.9)
Q4 (largest)	3171 (28.8)
Missing	155 (1.4)
Average dwelling sizes quintile	…
Q1 (fewest)	2251 (20.4)
Q2	2041 (18.5)
Q3	2369 (21.5)
Q4	1812 (16.4)
Q5 (largest)	2416 (21.9)
Missing	150 (1.4)
Household with persons <5 y quintile	…
Q1 (fewest)	1872 (17.0)
Q2	1846 (16.7)
Q3	1905 (17.3)
Q4	2139 (19.4)
Q5 (largest)	3127 (28.3)
Missing	150 (1.4)
Rurality	…
Rural	1427 (12.9)
Urban	9602 (87.0)
Public health region	…
Central East	2869 (26.0)
Central West	2879 (26.1)
East	1549 (14.0)
North East	306 (2.8)
North West	167 (1.5)
South West	1291 (11.7)
Toronto	1978 (17.9)

Abbreviation: RSV, respiratory syncytial virus.

[a]Unsuitable housing refers to having fewer bedrooms for the size and composition of the household, according to the National Occupancy Standard. Unsuitable housing is divided into quartiles due to disproportionate distribution of cases when in quintiles.

We used the ON-Marg index to assign each individual to a level of marginalization based on their lived neighborhood [21, 27]. Cases were assigned to DAs based on postal code of residence using the Postal Code Conversion File (PCCF)

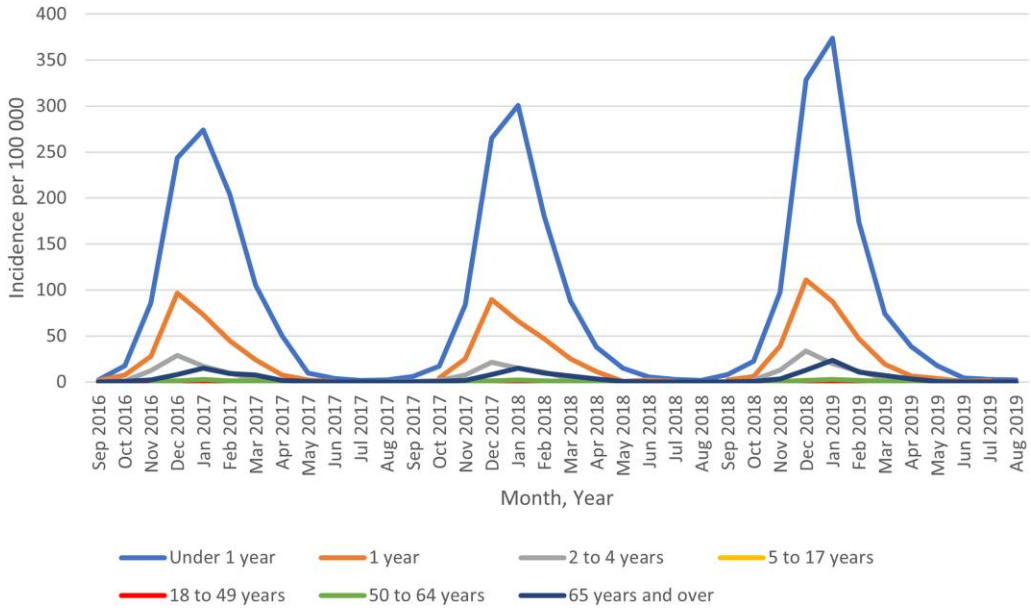

Figure 1. Age-specific monthly RSV-related hospitalization rates, September 1, 2016, to August 31, 2019. Abbreviation: RSV, respiratory syncytial virus.

Plus, version 7E [28]. ON-Marg index values and census indicators were categorized into quintiles, derived by ranking all Ontario DAs on their ON-Marg or census indicator values and categorizing them into 5 equal groups, ordered from Quintile (Q) 1 (eg, least marginalized/least multigenerational, etc.) to Q5 (most marginalized/most multigenerational, etc.).

Statistical Analysis

Hospitalization rates and rate ratios (RRs), along with associated 95% CIs, were calculated overall and by demographic, sociodemographic, and housing characteristics.

Age-specific rates were calculated for RSV-related hospitalizations among those aged <12 months, 12–23 months, 2–4 years, 5–17 years, 18–49 years, 50–64 years, and ≥65 years. RSV-related hospitalization rates for sociodemographic and housing characteristics were stratified by broader age groups at admission (<5, 5–64, ≥65 years) to account for the larger number of cases in young children and older adults. Annualized hospitalization incidence was calculated using the cumulative number of RSV-related hospitalizations as the numerator and the 2016 Ontario portion of the Canadian census, multiplied by 3 to account for the 3 RSV seasons, as the denominator. Rates for the sociodemographic and housing characteristics were age-standardized using the 2016 Ontario portion of the Canadian census by <5, 5–64, and ≥65 years of age to account for age differences between quintiles. Demographic, sociodemographic, and housing characteristics were further stratified by ICU admission and death in hospital, following RSV-related hospitalization. Additionally, the cumulative proportion of RSV-related hospitalization by month was stratified by age to observe growth in cases.

We conducted sensitivity analyses with RSV as the most responsible diagnosis. Further, we examined the top 5 most responsible diagnoses of patients without RSV as their most responsible diagnosis by age.

We obtained ethical approval from Public Health Ontario's Research Ethics Board. Statistical analyses were performed in SAS, version 9.4. The analysis code can be found in the Appendix.

RESULTS

Study Population

A total of 11 039 RSV-related hospitalizations were included in the 3-year study period, with most of these occurring among patients aged <12 months (38.5%), aged ≥65 years (31.5%) and aged 12–23 months (10.9%), as illustrated in Table 1. RSV-related hospitalizations most frequently occurred during winter months (December [25.5%], January [30.6%], and February [17.8%]). The cumulative proportion of RSV-related hospitalizations rose fastest in those aged 2–4 years and aged 12–23 months, followed by those aged <12 months (Supplementary Figure 2).

Age-Specific Patterns of Annual and Monthly RSV-Related Hospitalization Rate

Throughout the study period, the rate of RSV-related hospitalizations exhibited clear seasonality increasing from September to a peak in January across the 3 seasons before declining again to lows in July and August (Figure 1). The highest rates were

Table 2A. Crude Annualized RSV-Related Hospitalization Rates per 100 000 in Ontario by Demographic Characteristics

Characteristic	RSV-Related Hospitalizations, 2016–2019, No. (%)	Ontario Population, 2016	Annualized RSV-Related Hospitalization Rate per 100 000[a] (95% CI)
Overall	11 039	13 448 155	…
Demographic	…	…	…
Age	…	…	…
<12 mo	4252 (38.5)	135 080	1049.3 (1017.7–1080.8)
12–23 mo	1200 (10.9)	135 875	294.4 (277.7–311.0)
2–4 y	959 (8.7)	426 510	74.9 (70.2–79.7)
5–17 y	260 (2.4)	1 985 175	4.4 (3.8–4.9)
18–49 y	250 (2.3)	5 618 050	1.5 (1.3–1.7)
50–64 y	638 (5.8)	2 892 625	7.4 (6.8–7.9)
≥65 y	3480 (31.5)	2 249 625	51.6 (49.8–53.3)
65–74 y	908 (8.2)	1 265 375	23.9 (22.4–25.5)
75–84 y	1172 (10.6)	683 330	57.2 (53.9–60.4)
≥85 y	1400 (12.7)	300 920	155.1 (147.0–163.2)
Sex	…	…	…
Female	5580 (50.6)	6 888 235	27.0 (26.3–27.7)
Male	5459 (49.5)	6 554 705	27.8 (27.0–28.5)
Season[b]	…	…	…
2016–2017	3443 (31.2)	13 448 155	25.6 (24.7–26.5)
2017–2018	3379 (30.6)	13 448 155	25.1 (24.3–26.0)
2018–2019	4217 (38.2)	13 448 155	31.4 (30.4–32.3)
Month	…	…	…
September	56 (0.5)	13 448 155	0.1 (0.1–0.2)
October	171 (1.6)	13 448 155	0.4 (0.4–0.5)
November	838 (7.6)	13 448 155	2.1 (1.9–2.2)
December	2814 (25.5)	13 448 155	7.0 (6.7–7.2)
January	3376 (30.6)	13 448 155	8.4 (8.1–8.7)
February	1962 (17.8)	13 448 155	4.9 (4.6–5.1)
March	1099 (10.0)	13 448 155	2.7 (2.6–2.9)
April	481 (4.4)	13 448 155	1.2 (1.1–1.3)
May	146 (1.3)	13 448 155	0.4 (0.3–0.4)
June	43 (0.4)	13 448 155	0.1 (0.1–0.1)
July	23 (0.2)	13 448 155	0.1 (0.0–0.1)
August	30 (0.3)	13 448 155	0.1 (0.0–0.1)

Missing rates were not included in the table.

Abbreviation: RSV, respiratory syncytial virus.

[a]Annualized rate is calculated using the cumulative number of RSV-related hospitalizations from September 1, 2016, to August 31, 2019, as the numerator and the 2016 Ontario census multiplied by 3 as the denominator.

[b]Rate for season is calculated using the cumulative number of RSV-related hospitalizations from September 1, 2016, to August 31, 2019, as the numerator and the 2016 Ontario census as the denominator.

consistently seen among patients aged <12 months, followed by those aged 12–23 months, 2–4 years, and ≥65 years.

Age-Standardized Patterns of RSV-Related Hospitalization Rate

The highest annual incidence of hospitalizations attributable to RSV infections was found in patients aged <12 months (927.8 per 100 000; 95% CI, 898.2–957.5), followed by those aged 12–23 months (294.4 per 100 000; 95% CI, 277.7–311.0) and ≥85 years (155.1 per 100 000; 95% CI, 147.0–163.2) (Table 2A). No differences in RSV-related hospitalization rates were observed by sex. Overall, the age-standardized RSV-related hospitalization rate was 27.3 cases per 100 000, which varied across sociodemographic characteristics (Table 2B). There was no clear gradient in RSV-related hospitalizations across quintiles of the racialized and newcomer populations index. We observed an increase in RSV-related hospitalization associated with increasing material resource–related marginalization (32.6 per 100 000 vs 24.1 per 100 000) (Figure 2). In terms of the households and dwellings dimension, neighborhoods with the most households and dwellings–related marginalization exhibited higher rates of hospitalization compared with the least marginalized neighborhoods (31.4 per 100 000 vs 21.5 per 100 000). Increasing age and labor force–related marginalization was associated with an increase in RSV-related hospitalization rates (30.9 per 100 000 vs 24.9 per 100 000).

We observed an inverse gradient between many housing characteristics and age-standardized RSV-related hospitalization rates. For example, this was evident in comparing the lowest with the highest quintiles of multigenerational families (29.1 per 100 000 vs 24.5 per 100 000), unsuitable housing (31.4 per 100 000 vs 21.5 per 100 000), average dwelling size (31.1 per 100 000 vs 22.8 per 100 000), and households with children aged <5 years (32.5 per 100 000 vs 25.4 per 100 000). Among Ontario's public health regions, the hospitalization incidence varied from 19.3 per 100 000 to 36.1 per 100 000.

Age-stratified trends consistently aligned with overall age-standardized trends in the material resources, housing and dwellings, and age and labor force indices (Supplementary Figure 3). Specifically, among those aged ≥65, the hospitalization rate increased 2-fold from increasing households and dwellings–related marginalization (37.3 per 100 000 vs 76.7 per 100 000). This 2-fold increase was also observed between the areas with the lowest and highest concentrations of the racialized and immigrant populations index. However, for those aged <5 years, a decrease in hospitalization rates was observed with increasing neighborhood-level quintile of racialized and immigrant populations marginalization (376.3 per 100 000 vs 240.7 per 100 000). RSV hospitalization rates also increased with increasing households and dwellings–related marginalization (251.9 per 100 000 vs 302.4 per 100 000). These gradients were also mirrored consistently across age groups.

In-Hospital Outcomes

Among all RSV-related hospital admissions, 15.1% were admitted to the ICU and 3.5% experienced an in-hospital death (Table 3). ICU admissions were most common among those aged 18–49 years (27.6%). Death in hospital was more common among those aged ≥65 (7.0%), and the median length of stay for RSV-related hospitalization was longest in this age group as well, followed by the 50–64 age group (Supplementary

Table 2B. Age-Standardized Annualized RSV-Related Hospitalization Rates per 100 000 in Ontario by Sociodemographic and Housing Characteristics

Characteristic	RSV-Related Hospitalizations, 2016–2019, No. (%)	Ontario Population, 2016	Age-Standardized Annualized RSV-Related Hospitalization Rate per 100 000a (95% CI)	Rate Ratio (95% CI)
Overall	11 039	13 448 155	27.3 (26.4–28.2)	-
Sociodemographic	…	…	…	…
Racialized and newcomer populations quintile (ON-Marg)	…	…	…	…
Q1 (least marginalized)	1617 (14.7)	2 074 090	28.2 (26.0–30.4)	1.0 (reference)
Q2	1905 (17.3)	2 209 735	29.2 (27.1–31.3)	1.0 (1.0–1.0)
Q3	2093 (19.0)	2 392 660	29.3 (27.2–31.3)	1.0 (1.0–1.0)
Q4	2354 (21.3)	2 827 935	28.6 (26.7–30.5)	1.0 (1.0–1.0)
Q5 (most marginalized)	2868 (26.0)	2 074 090	25.1 (23.5–26.6)	0.9 (0.9–0.9)
Material resources quintile (ON-Marg)	…	…	…	…
Q1 (least marginalized)	2169 (19.7)	3 027 125	24.1 (22.4–25.7)	1.0 (reference)
Q2	2018 (18.3)	2 832 470	24.0 (22.3–25.7)	1.0 (1.0–1.0)
Q3	1905 (17.3)	2 546 320	25.4 (23.6–27.2)	1.1 (1.1–1.1)
Q4	2128 (19.3)	2 432 020	29.5 (27.4–31.5)	1.2 (1.2–1.2)
Q5 (most marginalized)	2617 (23.7)	2 540 425	32.6 (30.6–34.7)	1.4 (1.4–1.4)
Households and dwellings quintile (ON-Marg)	…	…	…	…
Q1 (least marginalized)	1850 (16.8)	2 968 800	21.5 (19.9–23.1)	1.0 (reference)
Q2	1933 (17.5)	2 534 625	25.7 (23.9–27.6)	1.2 (1.2–1.2)
Q3	1928 (17.5)	2 392 230	26.4 (24.5–28.3)	1.2 (1.2–1.2)
Q4	2173 (19.7)	2 405 570	29.1 (27.1–31.1)	1.4 (1.3–1.4)
Q5 (most marginalized)	2953 (26.8)	3 077 135	31.4 (29.5–33.3)	1.5 (1.4–1.5)
Age and labor quintile (ON-Marg)	…	…	…	…
Q1 (least marginalized)	2682 (24.3)	3 656 515	24.9 (23.2–26.5)	1.0 (reference)
Q2	2134 (19.3)	2 745 855	27.1 (25.2–29.0)	1.1 (1.1–1.1)
Q3	1901 (17.2)	2 356 490	28.0 (26.0–30.1)	1.1 (1.1–1.1)
Q4	1820 (16.5)	2 242 400	27.7 (25.7–29.8)	1.1 (1.1–1.1)
Q5 (most marginalized)	2300 (20.8)	2 377 250	30.9 (28.7–33.1)	1.2 (1.2–1.2)
Housing	…	…	…	…
Multigenerational families quintile	…	…	…	…
Q1 (fewest)	2345 (21.2)	2 749 085	29.1 (27.2–31.0)	1.0 (reference)
Q2	1744 (15.8)	2 094 330	27.8 (25.7–30.0)	1.0 (0.9–1.0)
Q3	2263 (20.5)	2 732 730	27.2 (25.3–29.0)	0.9 (0.9–0.9)
Q4	2332 (21.1)	2 840 820	26.9 (25.1–28.7)	0.9 (0.9–0.9)
Q5 (largest)	2200 (19.9)	3 021 505	24.5 (22.9–26.2)	0.8 (0.8–0.8)
Unsuitable housing quartile[b]	…	…	…	…
Q1 (fewest)	3175 (28.8)	4 103 625	26.8 (25.3–28.3)	1.0 (reference)
Q2	1793 (16.2)	2 188 520	25.8 (23.8–27.7)	1.0 (0.9–1.0)
Q3	2745 (24.9)	3 258 440	28.3 (26.5–30)	1.1 (1.0–1.1)
Q4 (largest)	3171 (28.8)	3 887 885	27.6 (26.0–29.2)	1.0 (1.0–1.0)
Average dwelling sizes quintile	…	…	…	…
Q1 (fewest)	2251 (20.4)	2 477 800	31.1 (28.9–33.2)	1.0 (reference)
Q2	2041 (18.5)	2 353 065	28.8 (26.8–30.8)	0.9 (0.9–0.9)
Q3	2369 (21.5)	2 776 080	28.0 (26.2–29.8)	0.9 (0.9–0.9)
Q4	1812 (16.4)	2 263 490	26.6 (24.6–28.6)	0.9 (0.9–0.9)
Q5 (largest)	2416 (21.9)	3 569 875	22.8 (21.3–24.3)	0.7 (0.7–0.7)
Household with persons <5 y quintile	…	…	…	…
Q1 (fewest)	1872 (17.0)	2 365 265	32.5 (30.0–35.0)	1.0 (reference)
Q2	1846 (16.7)	2 439 210	28.5 (26.4–30.6)	0.9 (0.9–0.9)
Q3	1905 (17.3)	2 494 680	26.9 (24.9–28.8)	0.8 (0.8–0.8)
Q4	2139 (19.4)	2 675 160	26.2 (24.4–28.1)	0.8 (0.8–0.8)
Q5 (largest)	3127 (28.3)	3 465 995	25.4 (23.9–27.0)	0.8 (0.8–0.8)
Rurality	…	…	…	…
Rural	1427 (12.9)	1 848 105	26.0 (23.9–28.1)	1.0 (reference)
Urban	9602 (87.0)	11 600 050	27.6 (26.7–28.5)	1.1 (1.0–1.1)

Table 2B. Continued

Characteristic	RSV-Related Hospitalizations, 2016–2019, No. (%)	Ontario Population, 2016	Age-Standardized Annualized RSV-Related Hospitalization Rate per 100 000a (95% CI)	Rate Ratio (95% CI)
Public health region	…	…	…	…
Central East	2869 (26.0)	3 985 675	24.4 (23.0–25.9)	-
Central West	2879 (26.1)	2 602 740	36.1 (34.0–38.3)	-
East	1549 (14.0)	1 762 675	29.5 (27.2–31.9)	-
North East	306 (2.8)	550 490	19.3 (16.0–22.6)	-
North West	167 (1.5)	226 980	23.7 (18.2–29.2)	-
South West	1291 (11.7)	1 581 065	26.3 (24.0–28.6)	-
Toronto	1978 (17.9)	2 730 685	24.3 (22.5–26.1)	-

Missing rates were not included in the table.

Abbreviation: RSV, respiratory syncytial virus.

[a]Annualized rate is calculated using the cumulative number of RSV-related hospitalizations from September 1, 2016, to August 31, 2019, as the numerator and the 2016 Ontario census multiplied by 3 as the denominator.

[b]Unsuitable housing refers to having more household members occupying the same dwelling unit to live comfortably together, according to the National Occupancy Standard. Unsuitable housing is divided into quartiles due to disproportionate distribution of cases when in quintiles.

Table 1). Among patients aged ≥65 who died in hospital, the median length of stay was longest for those aged 75–84 years, followed by 65–74 years (Supplementary Table 2).

Trends by RSV Diagnosis

Among the 11 039 RSV-related hospitalizations, 6755 (61.2%) had 1 of the 4 RSV ICD-10-CA codes as the most responsible diagnosis (Supplementary Table 3). For those with RSV as their most responsible diagnosis, hospitalizations were also greatest among those aged <12 months (55.7%), ≥65 years (17.2%), and 12–23 months (13.0%). Cases most frequently occurred during the winter months: December (23.7%), January (29.2%), and February (17.9%). Trends across demographic characteristics and quintiles for sociodemographic and housing characteristics were consistent for RSV as the most responsible diagnosis and when considered in all diagnostic fields (Supplementary Table 4A and B). A larger gradient from low to high quintiles of marginalization was observed for multigenerational families (15.2 per 100 000 vs 20.4 per 100 000) for RSV as the most responsible diagnosis; however, an opposite gradient was noted when looking at all diagnoses.

For those with RSV as the most responsible diagnosis, 11.3% were admitted to the ICU and 1.4% experienced in-hospital mortality (Supplementary Table 5). The median length of stay was also highest among individuals aged ≥65 years with RSV as the most responsible diagnosis (Supplementary Table 1) and not the most responsible diagnosis (Supplementary Table 6). For cases where RSV was not the most responsible diagnosis, acute upper respiratory infection emerged as the most common diagnosis across all age groups, and individuals aged ≥65 also showed congestive heart failure among their top 5 most responsible diagnoses (Supplementary Table 7).

DISCUSSION

Between 2016 to 2019, we examined the age distribution of RSV-related hospitalization by calendar month, with the highest incidence among those aged <12 months followed by 12–23 months, 2–4 years, and ≥65 years in January. Higher rates of RSV-related hospitalization were observed in neighborhoods characterized by marginalization related to both material resources and households and dwellings, fewer households with children <5 years, and households with smaller dwelling sizes. These findings highlight how neighborhood conditions may be associated with RSV-related hospitalization inequities. This prepandemic study can provide a benchmark of the burden and seasonal patterns of RSV hospitalizations before the disruptive influence of the COVID-19 pandemic. Considerable shifts in age distribution and disease severity can be seen with the resurgence of RSV 2 years into the pandemic [29]. The introduction of new RSV vaccines and monoclonal antibodies would further alter these patterns by reducing RSV incidence and severity, particularly among high-risk groups.

Overall, RSV-related hospitalization rates were consistent with the Canadian literature; however, the magnitude of RSV-related hospitalization rates appears lower than US estimates [18, 30–32]. Direct comparisons of absolute rates are challenging given differences in study population, methodology, and time period. Trends in RSV-related hospitalizations varied by sociodemographic indices in our study neighborhoods, with higher marginalization of material resources exhibiting higher RSV-related hospitalization rates than less marginalized areas. This observation aligns with research exploring the association between income, poverty, and RSV infection [33, 34]. Lower parental education, an element within the material and resource index in our study, has also been associated with higher RSV infection [35]. This is consistent with findings from Fitzpatrick et al. (2021), who also found

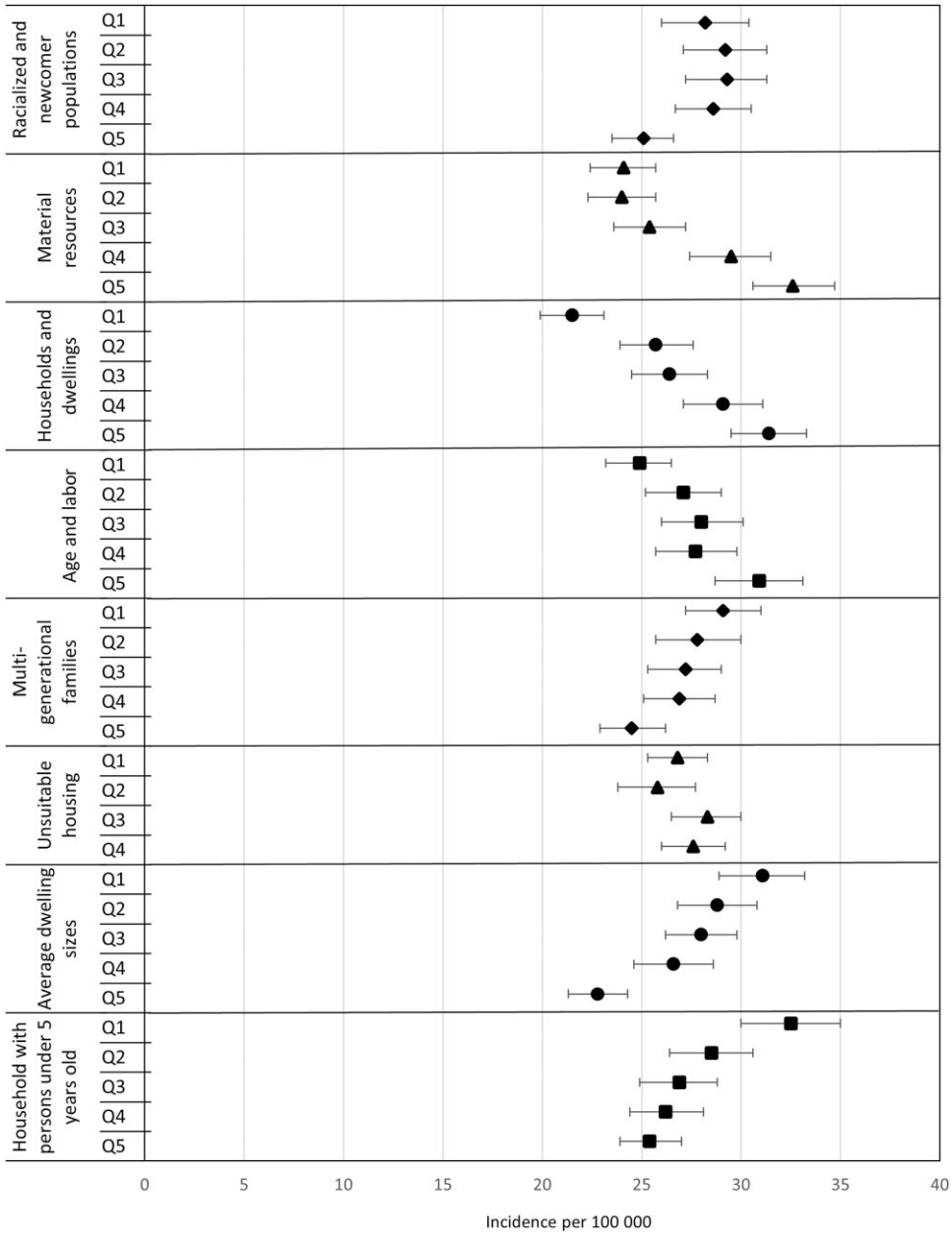

Figure 2. Age-standardized annualized RSV-related hospitalization rates per 100 000 in Ontario, by neighborhood-level sociodemographic and housing characteristics. Abbreviation: RSV, respiratory syncytial virus.

inequities in RSV-related hospitalizations among Ontario children across ON-Marg indices, noting that children born to recent immigrants had a lower risk of RSV-related hospitalization compared with Canadian-born populations. This phenomenon might be linked to the healthy immigrant effect or Canada's selective entry criteria for healthy and highly educated immigrants [14, 36]. Alternatively, limited access to care for racialized and newcomer populations may be due to systemic barriers or distrust, leading to a reluctance to seek medical attention for mild to moderate conditions. We also found higher rates of RSV-related hospitalization in neighborhoods experiencing greater marginalization related to households and dwellings, including poor housing conditions, smaller dwellings, and housing crowding, as noted by previous studies [14, 35, 37].

We also found that neighborhoods with fewer households with children aged <5 years had higher hospitalization rates. A possible explanation is that first-time mothers in households without other children aged <5 years may not have been exposed to infectious diseases as extensively as multiparous women, leading to potentially lower transfer of protective antibodies to their first child during childbirth [38]. Families with 2 or

Table 3. In-Hospital Outcomes Following RSV-Related Hospitalization From September 1, 2016, to August 31, 2019

Characteristic, No. (%)	ICU Admissions	Death in Hospital
No. (%) of those admitted	1661 (15.1)	382 (3.5)
Demographic	…	…
Age	…	…
<12 mo	570 (13.4)	1 (0.0)
12–23 mo	103 (8.6)	1 (0.1)
2–4 y	103 (10.7)	1 (0.1)
5–17 y	61 (23.5)	1 (0.4)
18–49 y	69 (27.6)	11 (4.4)
50–64 y	171 (26.8)	46 (7.2)
≥65 y	584 (16.8)	321 (9.2)
65–74 y	244 (26.9)	60 (6.6)
75–84 y	198 (16.9)	105 (9.0)
≥85 y	142 (10.1)	156 (11.1)
Sex	…	…
Female	850 (15.2)	201 (3.6)
Male	811 (14.9)	181 (3.3)
Sociodemographic	…	…
Racialized and newcomer populations quintile (ON-Marg)	…	…
Q1 (least marginalized)	264 (16.3)	56 (3.5)
Q2	298 (15.6)	56 (2.9)
Q3	308 (14.7)	68 (3.2)
Q4	349 (14.8)	89 (3.8)
Q5 (most marginalized)	407 (14.2)	110 (3.8)
Missing	35 (17.3)	3 (1.5)
Material resources quintile (ON-Marg)	…	…
Q1 (least marginalized)	316 (14.6)	76 (3.5)
Q2	292 (14.5)	69 (3.4)
Q3	262 (13.8)	57 (3.0)
Q4	318 (14.9)	78 (3.7)
Q5 (most marginalized)	438 (16.7)	99 (3.8)
Missing	35 (17.3)	3 (1.5)
Households and dwellings quintile (ON-Marg)	…	…
Q1 (least marginalized)	259 (14.0)	35 (1.9)
Q2	298 (15.4)	52 (2.7)
Q3	274 (14.2)	61 (3.2)
Q4	321 (14.8)	73 (3.4)
Q5 (most marginalized)	474 (16.1)	158 (5.4)
Missing	35 (17.3)	3 (1.5)
Age and labor quintile (ON-Marg)	…	…
Q1 (least marginalized)	386 (14.4)	48 (1.8)
Q2	311 (14.6)	62 (2.9)
Q3	290 (15.3)	66 (3.5)
Q4	288 (15.8)	67 (3.7)
Q5 (most marginalized)	351 (15.3)	136 (5.9)
Missing	35 (17.3)	3 (1.5)
Housing	…	…
Multigenerational families quintile	…	…
Q1 (fewest)	384 (16.4)	96 (4.1)
Q2	269 (15.4)	64 (3.7)
Q3	342 (15.1)	69 (3.0)
Q4	336 (14.4)	85 (3.6)
Q5 (largest)	303 (13.8)	61 (2.8)
Missing	27 (17.4)	7 (4.5)
Unsuitable housing quartile[a]	…	…
Q1 (fewest)	490 (15.4)	104 (3.3)
Q2	250 (13.9)	54 (3.0)
Q3	426 (15.5)	94 (3.4)
Q4 (largest)	468 (14.8)	123 (3.9)
Missing	27 (17.4)	7 (4.5)
Average dwelling sizes quintile	…	…
Q1 (fewest)	370 (16.4)	118 (5.2)
Q2	304 (14.9)	70 (3.4)
Q3	363 (15.3)	83 (3.5)
Q4	285 (15.7)	65 (3.6)
Q5 (largest)	312 (12.9)	42 (1.7)
Missing	27 (17.4)	4 (2.7)
Household with persons <5 y quintile	…	…
Q1 (fewest)	271 (14.5)	112 (6.0)
Q2	262 (14.2)	75 (4.1)
Q3	314 (16.5)	62 (3.3)
Q4	327 (15.3)	63 (2.9)
Q5 (largest)	460 (14.7)	66 (2.1)
Missing	27 (17.4)	4 (2.7)
Rurality	…	…
Rural	244 (17.1)	31 (2.2)
Urban	1415 (14.7)	351 (3.7)
Missing	2 (20.0)	0 (0.0)
Public Health Region	…	…
Central East	348 (12.1)	89 (3.1)
Central West	423 (14.7)	90 (3.1)
East	290 (18.7)	41 (2.6)
North East	53 (17.3)	10 (3.3)
North West	28 (16.8)	1 (0.6)
South West	219 (17.0)	44 (3.4)
Toronto	300 (15.2)	107 (5.4)

Abbreviation: RSV, respiratory syncytial virus.

[a]Unsuitable housing refers to having fewer bedrooms for the size and composition of the household, according to the National Occupancy Standard. Unsuitable housing is divided into quartiles due to disproportionate distribution of cases when in quintiles.

more siblings had no association with sibling infections occurring in 1 or multiple siblings [39]. Additionally, neighborhoods with higher proportions of multigenerational families and larger dwelling sizes had lower rates of RSV-related hospitalizations, which could be attributed to prior RSV exposures and the subsequent development of immunity within these larger family dynamics. This may also reflect the differential use of childcare where families with more older children and relatives use less childcare, thereby limiting a risk factor for childhood infection [39].

In our study, the proportion of deaths in-hospital was highest for older populations, which is consistent with other studies [31, 40–42]. Further, the proportion of hospitalized cases admitted to the ICU was highest in those aged ≥85 years. This is likely due to RSV-hospitalized individuals in this age group likely being immunocompromised and potentially

having more underlying high-risk conditions, such as chronic obstructive pulmonary disease (COPD), asthma, and congestive heart failure, which can heighten susceptibility to severe RSV infections [40]. In addition, ICU admission was highest among 18–49-year-olds, which was unexpected as RSV-related hospitalizations are less common in younger adult populations. While RSV reinfection is common throughout adult life, healthy young adults produce mild symptoms following infection [43]. The higher rates of ICU admission among individuals aged 18–49 years could be attributed to comorbidities [44].

This study has notable strengths, foremost among them being its novel exploration of social risk factors in RSV-related hospitalization across all age groups, which is a unique contribution to our understanding of RSV in Canada. Unlike existing research that often focuses on limited age ranges, this study explores the entirety of the age spectrum, making its findings more comprehensive and applicable to diverse populations. Additionally, we examined a wide array of demographic variables, allowing for a nuanced understanding of the intricate interplay between social determinants and RSV-related hospitalization rates. We further expanded sociodemographic exposures to include an aggregate of sociodemographic factors using the ON-Marg index and more information on housing characteristics, shedding light on the interaction of social and environmental factors in disease outcomes. This study used a population-based approach, which addressed the limitations in other studies, such as Medicaid-focused research in the United States, with limited generalizability across a spectrum of socioeconomic statuses. Findings from a population-based study may have broader implications in informing targeted interventions for a diverse range of socioeconomic groups. We also looked at both RSV diagnoses as all possible diagnoses and the most responsible diagnosis in our study to capture the full burden of RSV-related hospitalization. Relying solely on the most responsible diagnosis may not fully capture the true burden of RSV-related hospitalization, as cases might be coded for comorbidities like COPD exacerbation despite being primarily RSV-related [19]. In addition, relying on a validated algorithm to define RSV-related hospitalization can capture a wider range of cases, given the low rate of laboratory confirmation [19].

However, this study is also subject to some limitations. First, our study focuses solely on hospitalized RSV cases, thus not providing a comprehensive assessment of the overall RSV burden. There may also be an underestimation of RSV hospital admissions as not all cases are tested or recorded as RSV. Our study may particularly underestimate RSV-related hospitalization rates in adults compared with pediatric age groups due to differences in algorithm sensitivity [45]. Further, focusing solely on hospitalized cases neglects the prevalence of outpatient RSV cases, omitting crucial information regarding ambulatory care that often precedes hospitalization and varies based on socioeconomic contexts. Although our study relies on ICD-10-coded outcomes, there is a possibility of misclassification; however, the RSV codes included have been previously validated and have high sensitivity and specificity [19]. Comorbidities were not examined in our study, which may contribute to differential rates across age and social risk factors.

CONCLUSIONS

In conclusion, the highest incidence of RSV-related hospitalization was seen in neighborhoods with greater material resources as well as households and dwellings–related marginalization. The highest burden of RSV was seen in those aged <5 and ≥65 years. Improving our understanding of the relative burdens of RSV across the age continuum will aid the implementation of prevention efforts, particularly with the current expansions of existing vaccination recommendations and the development of new vaccines. Sociodemographic factors play a critical role in shaping RSV-related hospitalization, and these relationships can provide a baseline against which to measure the impact of future intervention efforts on health disparities and complement ongoing work that is being done with RSV burden. With upcoming vaccine decisions, baseline RSV-related hospitalization rates across sociodemographic factors can support the prioritization of high-risk groups and equity-informed decisions for future vaccine rollout and monitoring.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Acknowledgments

Author contributions. Kitty Y. A. Chen: methodology, formal analysis, writing—original draft preparation, writing—review & editing, visualization. Trevor van Ingen: methodology, formal analysis, writing—review & editing. Brendan T. Smith: conceptualization, writing—review & editing. Tiffany Fitzpatrick: conceptualization, writing—review & editing. Michael Whelan: writing—review & editing. Alyssa S. Parpia: writing—review & editing. Jenna Alessandrini: writing—review & editing. Sarah A. Buchan: conceptualization, methodology, formal analysis, writing—review & editing, supervision, project administration, financial support acquisition.

Ethical approval. The study was approved by the Ethics Review Board of Public Health Ontario (2019–062.02, approval 2019-Nov-12).

Informed consent. Patient consent was waived due to use of existing health administrative data used for secondary data analysis.

Data availability. Public Health Ontario (PHO) cannot disclose the underlying data. Doing so would compromise individual privacy contrary to PHO's ethical and legal obligations. Restricted access to the data may be available under conditions prescribed by the Ontario Personal Health Information Protection Act, 2004, the Ontario Freedom of Information and Protection of Privacy Act, the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2 [2022]), and PHO privacy and ethics policies. Data are available for researchers who meet PHO's criteria for access to confidential data. Information about PHO's data access request process is available online at https://www.publichealthontario.ca/en/data-and-analysis/using-data/data-requests.

Financial support. This study was supported by a SickKids–Canadian Institutes of Health Research New Investigator Grant in Child and Youth Health (NI19–1065) and by Public Health Ontario.

Potential conflicts of interest. The authors do not have a commercial or other association that might pose a conflict of interest.

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