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Enhanced Epidemiological Summary

(ARCHIVED) COVID-19 Case Fatality, Case Identification, and Attack Rates in Ontario

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This report includes the most current information available from the integrated Public Health Information System (iPHIS) as of **4 p.m. May 17, 2020**, and from the Toronto Public Health Coronavirus Rapid Entry System (CORES), the Ottawa Public Health COVID-19 Ottawa Database (The COD), and the Middlesex-London COVID-19 Case and Contact Management tool (CCMtool) as of **2 p.m. May 17, 2020**.

Purpose

For a number of reasons, only a portion of COVID-19 infections in the community are identified and reported as cases. In the absence of seroprevalence studies for Ontario, this report provides estimates of the proportions of infections that are identified as cases in Ontario, and estimates attack rates adjusted for differential case detection across age groups. An accurate estimation of case identification is important to have a realistic understanding of readiness for lifting physical distancing measures and to assist in estimating the increase in testing capacity that may be required for greater case detection.

Highlights

- The estimates provided in this report are back-calculated from stratum-specific case fatality, based on the assumption that all COVID-19-associated deaths are identified, while non-fatal COVID-19 cases are likely to not be identified.
- As of May 17, 2020, there have been 1,904 deaths reported in Ontario and 17,638 cases have recovered. Estimated case fatality adjusted for censoring (i.e., only considering those alive at each time point) at 60 days since symptom onset is currently 9.9%.
- We estimate that 0.6% (N=89,839) of the Ontario population has been infected with COVID-19, in contrast to 0.2% (N=22,942) of the population who have been reported as confirmed cases as of May 17, 2020.

- When comparing the number of detected cases to the number of estimated infections, we estimate that 25.5% of COVID-19 infections in Ontario have been detected. Age-specific case detection ranged from 20.5% in the 70–79 year age group, to 31.6% in the 30–39 year age group. Case detection could not be precisely measured in children by this method, since no deaths have been reported in Ontario children.

- Estimated attack rates in persons 80 and older are 4 times higher (N=23,097, representing 3.6% of the 80+ population) than in all other age groups, before and after adjustment for case detection.

- Based on infection fatality estimates from the published literature,[1] we estimate that Ontario's infection fatality ratio is 2.8% after accounting for the estimated age distribution of COVID-19 infections in Ontario. This estimate of infection fatality is substantially higher than those from other jurisdictions due to high estimated attack rates in the elderly.

- Sensitivity analyses demonstrated that: (1) halving estimates of case detection in children had little impact on overall estimated case detection, (2) alternate estimates of the infection fatality ratio yielded similar estimates of detection, and (3) if 33% of COVID-19-associated deaths were missed, this would suggest that our true case detection was 17.0%.

Methods

- All analyses were based on Ontario confirmed case data extracted from iPHIS, CORES, The COD, and CCMtool.

- Ontario population projection data for 2020 were sourced from Ontario Ministry of Health, IntelliHEALTH Ontario. Data were extracted on November 26, 2019.

- Analyses were conducted using R statistical software.

Case fatality ratio (CFR)

- The case fatality ratio is the proportion of identified cases that succumb to the infection. Crude estimates of case fatality per age group were calculated by dividing the total number of reported deaths by the total number of reported cases in each group. Crude estimates of case fatality are likely to be underestimates because not all cases have been followed for a sufficient number of days to be accurately classified as either recovered or deceased (censoring bias).

- Estimates of case fatality adjusted for censoring were calculated from Kaplan-Meier cumulative hazard estimates with days since symptom onset as the time scale. We considered all cases since the date that the first case in Ontario was reported in late January, 2020. Cases were censored at their death date.

    - We used estimated case fatality at 60 days since symptom onset, as by 60 days of follow-up all deaths had occurred (Figure 1)

    - For cases who were missing symptom onset date in their record (N=9,404; 41%), we imputed the date using a Generalized Additive Mixed Model. Case reported date (the date that the case was reported to the local public health unit), sex, and a random intercept for public health unit were used to impute the delay in days between symptom onset date and

case reported date. The imputed delay was then subtracted from case reported date to obtain an estimate of symptom onset date.

- For fatal cases whose death date preceded their reported symptom onset date (N=14), or for fatal cases who were missing a death date (N=5), we censored them at their symptom onset date.

Infection fatality ratio (IFR)

- Age-specific infection fatality estimates were drawn from Verity et al.,[1] and represents the proportion of persons infected with COVID-19 (including both those identified as cases and those that go undetected) that subsequently die.

- The overall infection fatality ratio for Ontario was calculated as the sum of the age-specific infection fatality ratios, weighted by the estimated proportion of infections per age group.

Case detection

- Case detection for each age group was estimated as the infection fatality ratio divided by the adjusted case fatality ratio, following Russell et al.[2] The estimated number of infections for each age group was then obtained by dividing the number of reported cases by the estimated case detection.

- Total estimated infections for Ontario was calculated as the sum of estimated infections across age groups. Overall case detection for Ontario was calculated as the total number of reported cases divided by the total number of estimated infections.

- As no deaths have been reported in Ontario in individuals aged 0–9 and 10–19, age-specific case detection could not be derived from the CFR. We assumed case detection in these age groups was equal to that of the closest age group with available data (20–29 years).

- We performed several sensitivity analyses in order to better account for the impacts of underlying assumptions, including: (1) lowering the estimated percent detection in individuals aged 0-9 and 10-19 years by half, (2) using alternate estimates of infection fatality,[3] and (3) increasing the number of reported deaths in each age group by 50% (except for age groups that had no reported deaths).

    - Reported deaths were inflated to assess the impact of potential under-detection of COVID-19 deaths. An inflation factor of 50% was chosen since, on average, several European countries reported under-detections of 50% in an analysis conducted by the New York Times.[4]

Attack Rate

- We calculated detected attack rates in the province by dividing the number of reported cases within an age group by the estimated population from that age group. Similarly, the detected attack rate for Ontario was calculated as the total number of reported cases divided by the estimated population of Ontario.

- We repeated this analysis using our estimated number of infections to calculate estimated attack rates.

Limitations

- This report includes confirmed cases of COVID-19 as per the Ontario Ministry of Health case definition, which may change over time.[5] Case detection is strongly influenced by the provincial testing strategy and will be unlikely to capture infections in population groups not prioritized for testing (i.e., the number of detected cases are an under-estimate of the total number of infections).
    - As health care workers are prioritized for testing, there may be some testing bias in the 20–59 year age groups. This could result in underestimates of CFRs, and overestimates of case detection, due to the healthy worker effect.
    - We were unable to obtain separate estimates of infection fatality for elderly community-dwelling individuals versus elderly individuals that reside in institutional settings, such as long-term care homes. Case fatality in these two groups differs due to increased risk factors and/or underlying conditions among those residing in these settings. In Ontario, there have been numerous outbreaks in long-term care homes and a high proportion of deaths among those in long-term care residency. This contributes to lower estimates of case detection in the 70+ year age groups (i.e., a high proportion of deaths in this age group are amongst those residing in LTC which contributes to an elevated CFR and thus the ratio between IFR and CFR is lower).
- The data only represent cases reported to public health and entered in iPHIS, CORES, The COD, or CCMtool. As a result, the number of reported cases, as well as case details, are subject to underreporting owing to factors such as illness awareness, illness severity, medical care seeking behaviour, clinical practice, laboratory testing algorithms, and reporting practices. Reported case counts may also be underestimates due to delays in data entry.
- COVID-19 deaths are likely under-reported as these events may occur after the completion of public health follow up of cases, and because infections (even fatal ones) may never receive confirmatory testing. Cases that died after follow-up was completed may not be captured in iPHIS, CORES, The COD, or CCMtool. Further, there is emerging evidence of substantial excess mortality during the COVID-19 pandemic, beyond those reported as COVID-19 deaths. We used a sensitivity analysis to address this limitation.
- Estimates of case detection in children using this methodology may be unreliable, due to the low infection fatality in younger persons. We addressed this with a sensitivity analysis, but it remains possible that our estimates in younger age groups are inaccurate.
- Estimates of case detection are based on age-specific infection fatality ratios from Verity et al.,[1] and are subject to substantial uncertainty. If true infection fatality ratios are lower than those reported by Verity et al., these results may represent overestimates of case detection. New evidence from serological studies will yield more accurate estimates of case detection and could be used to adjust the estimates provided in this analysis.

- iPHIS, CORES, The COD, and CCMtool are dynamic disease reporting systems, which allow ongoing updates to data previously entered. As a result, data extracted represent a snapshot at the time of extraction and may differ from previous or subsequent reports.

Estimates of case detection by age group

Table 1. Estimates of case detection by age group, January 25 to May 17, 2020.

Age group	Population	Reported cases	Detected attack rate per 100,000	Reported deaths	IFR (%)[†]	CFR (%, crude)	CFR (%, adjusted censoring)	Estimated detection (%)	Estimated number of infections	Estimated attack rate per 100,000
0–9*	1,518,527	179	11.8	0	0.002	0	0	28.0[‡]	639	42.1
10–19*	1,617,937	465	28.7	0	0.007	0	0	28.0[‡]	1,662	102.7
20–29	2,100,175	2,729	129.9	2	0.031	0.07	0.11	28.0	9,756	464.5
30–39	2,056,056	2,838	138.0	6	0.084	0.21	0.27	31.6	8,977	436.6
40–49	1,876,585	3,179	169.4	17	0.161	0.54	0.67	24.0	13,219	704.4
50–59	2,060,937	3,841	186.4	62	0.595	1.61	2.03	29.3	13,106	635.9
60–69	1,795,047	2,824	157.3	154	1.93	5.45	6.52	29.6	9,536	531.2
70–79	1,159,898	2,018	174.0	331	4.28	16.40	20.89	20.5	9,847	849.0
80+	679,266	4,869	716.8	1,332	7.80	27.36	37.00	21.1	23,097	3,400.3
Total	**14,864,428**	**22,942[§]**	**154.3**	**1,904**	**2.80**	**8.29**	**9.93**	**25.5**	**89,839**	**604.4**

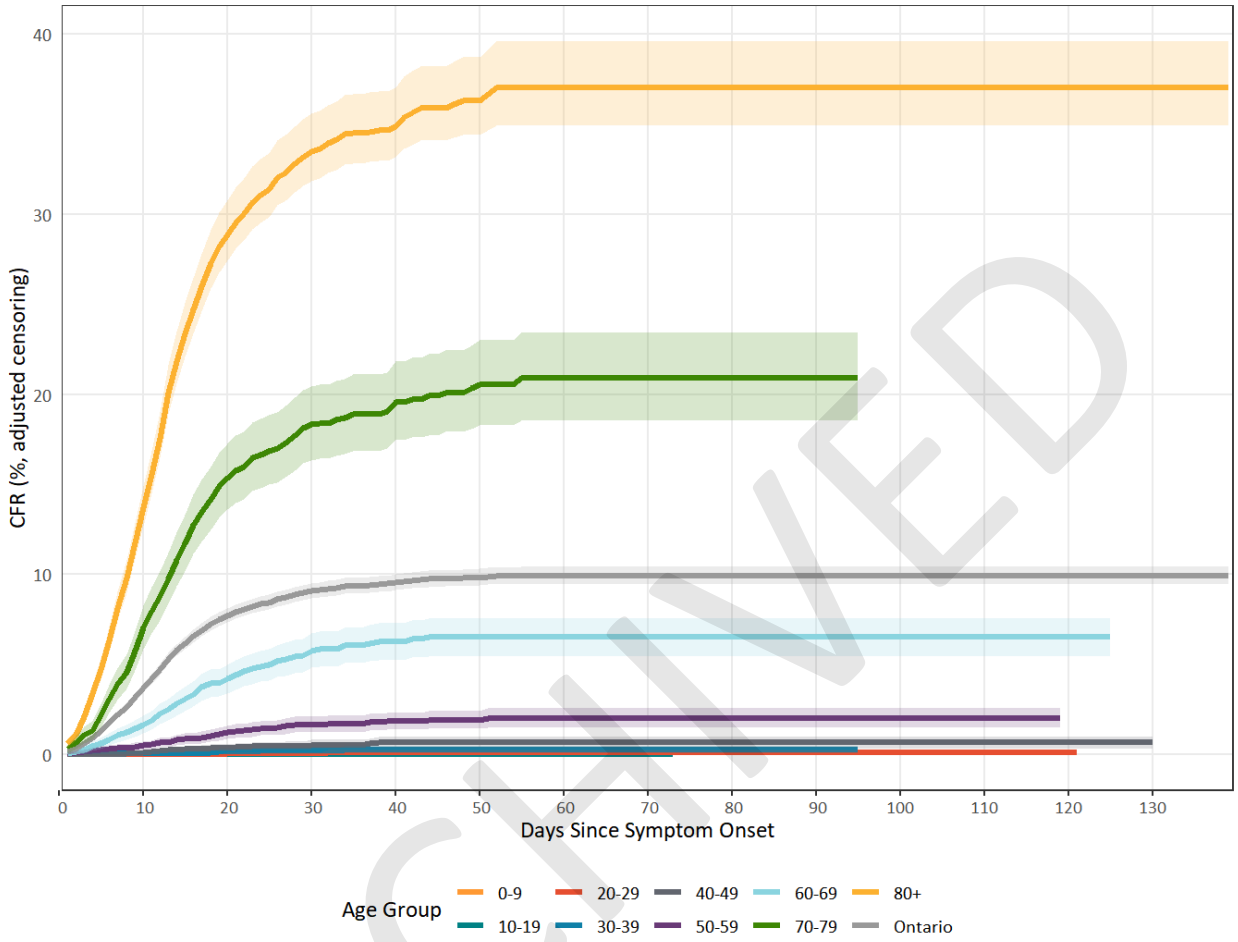
*Estimated number of deaths based on 20% case detection remains substantially below 1 for each of these groups, which suggests that a wide range of case detection proportions are possible.

[†]Age-specific estimates drawn from Verity et al.[1] and the total IFR was standardized to Ontario's age distribution of infections.

[‡]Case detection could not be directly estimated using age-specific CFR and was assumed to be the same as the closest age group with available data (20–29 years).

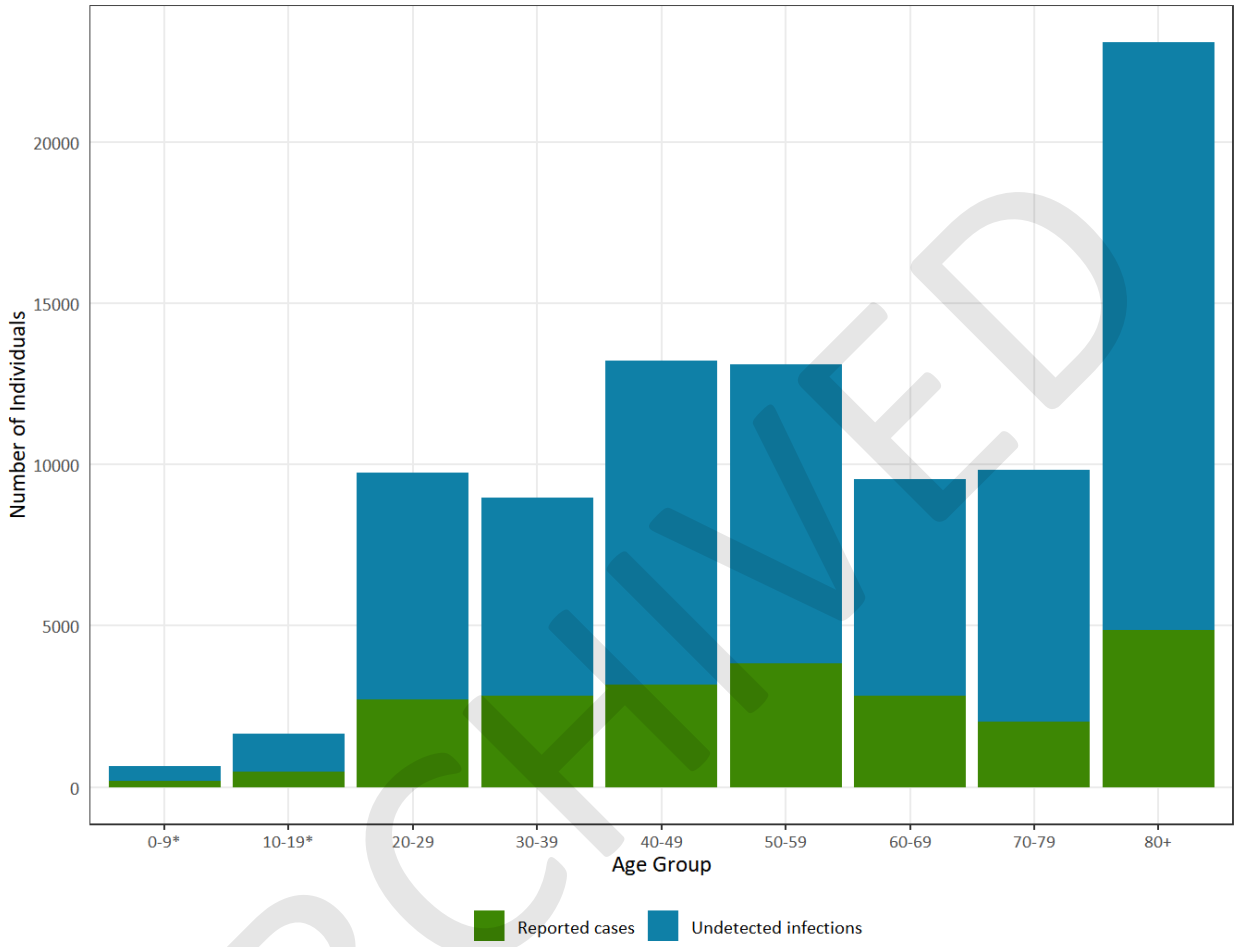
[§]15 cases were excluded due to missing age information.

Figure 1. COVID-19 case fatality in Ontario by age group, January 25 to May 17, 2020.



Note: shaded regions represent 95% confidence intervals.

Figure 2. Estimated number of COVID-19 infections and reported cases in Ontario by age group, January 25 to May 17, 2020.



*Case detection could not be directly estimated using age-specific CFR and was assumed to be the same as the closest age group with available data (20–29 years).

Sensitivity Analysis 1: Lower estimated % detection in 0–9 and 10–19 age groups by half.

Age group	Population	Reported cases	Detected attack rate per 100,000	Reported deaths	IFR (%)	CFR (%, crude)	CFR (%, adjusted censoring)	Estimated detection (%)	Estimated number of infections	Estimated attack rate per 100,000
0–9	1,518,527	179	11.8	0	0.002	0	0	14.0*	1,279	84.2
10–19	1,617,937	465	28.7	0	0.007	0	0	14.0*	3,324	205.4
20–29	2,100,175	2,729	129.9	2	0.031	0.07	0.11	28.0	9,756	464.5
30–39	2,056,056	2,838	138.0	6	0.084	0.21	0.27	31.6	8,977	436.6
40–49	1,876,585	3,179	169.4	17	0.161	0.54	0.67	24.0	13,219	704.4
50–59	2,060,937	3,841	186.4	62	0.595	1.61	2.03	29.3	13,106	635.9
60–69	1,795,047	2,824	157.3	154	1.93	5.45	6.52	29.6	9,536	531.2
70–79	1,159,898	2,018	174.0	331	4.28	16.40	20.89	20.5	9,847	849.0
80+	679,266	4,869	716.8	1,332	7.80	27.36	37.00	21.1	23,097	3,400.3
Total	**14,864,428**	**22,942**	**154.3**	**1,904**	**2.73**	**8.29**	**9.93**	**24.9**	**92,141**	**619.9**

Note: changes from the main analysis are signified by *.

Sensitivity Analysis 2: Use alternate estimates of IFR (Ferguson et al.[3]).

Age group	Population	Reported cases	Detected attack rate per 100,000	Reported deaths	IFR (%)	CFR (%, crude)	CFR (%, adjusted censoring)	Estimated detection (%)	Estimated number of infections	Estimated attack rate per 100,000
0–9	1,518,527	179	11.8	0	0.002*	0	0	27.2	659	43.4
10–19	1,617,937	465	28.7	0	0.006*	0	0	27.2	1,712	105.8
20–29	2,100,175	2,729	129.9	2	0.03*	0.07	0.11	27.2	10,049	478.5
30–39	2,056,056	2,838	138.0	6	0.08*	0.21	0.27	30.0	9,470	460.6
40–49	1,876,585	3,179	169.4	17	0.15*	0.54	0.67	22.4	14,188	756.1
50–59	2,060,937	3,841	186.4	62	0.6*	1.61	2.03	29.6	12,997	630.6
60–69	1,795,047	2,824	157.3	154	2.2*	5.45	6.52	33.8	8,366	466.1
70–79	1,159,898	2,018	174.0	331	5.1*	16.40	20.89	24.4	8,264	712.5
80+	679,266	4,869	716.8	1,332	9.3*	27.36	37.00	25.1	19,372	2,851.9
Total	**14,864,428**	**22,942**	**154.3**	**1,904**	**2.96**	**8.29**	**9.93**	**27.0**	**85,077**	**572.4**

Note: changes from the main analysis are signified by *.

Sensitivity Analysis 3: Adjust for potential underreporting of deaths by increasing reported death counts by 50%.

Age group	Population	Reported cases	Detected attack rate per 100,000	Adjusted deaths	IFR (%)	CFR (%, crude)	CFR (%, adjusted censoring)	Estimated detection (%)	Estimated number of infections	Estimated attack rate per 100,000
0–9	1,518,527	179	11.8	0	0.002	0	0	18.6	959	63.2
10–19	1,617,937	465	28.7	0	0.007	0	0	18.6	2,493	154.1
20–29	2,100,175	2,729	129.9	3*	0.031	0.11*	0.17*	18.6	14,634	696.8
30–39	2,056,056	2,838	138.0	9*	0.084	0.32*	0.40*	21.1	13,465	654.9
40–49	1,876,585	3,179	169.4	25*	0.161	0.80*	1.00*	16.0	19,828	1,056.6
50–59	2,060,937	3,841	186.4	93*	0.595	2.42*	3.05*	19.5	19,659	953.9
60–69	1,795,047	2,824	157.3	231*	1.93	8.18*	9.78*	19.7	14,304	796.9
70–79	1,159,898	2,018	174.0	496*	4.28	24.60*	31.33*	13.7	14,771	1,273.5
80+	679,266	4,869	716.8	1,998*	7.80	41.04*	55.50*	14.1	34,646	5,100.5
Total	**14,864,428**	**22,942**	**154.3**	**2,855**	**2.80**	**12.44**	**14.89**	**17.0**	**134,759**	**906.6**

Note: changes from the main analysis are signified by *.

References

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