Public Health Agency of Canada

COVID-19

CCDR Publication Summary

CANADA COMMUNICABLE DISEASE REPORT

The Canada Communicable Disease Report is a bilingual, open-access, peer-reviewed journal on the prevention and control of emerging and persistent infectious diseases.

Assessing the impact of varying levels of case detection and contact tracing on COVID-19 transmission in Canada during lifting of restrictive closures using a dynamic compartmental model

This paper presents a mathematical research model developed by the Public Health Agency of Canada (PHAC) and Statistics Canada that assesses several non-pharmaceutical interventions (NPIs) on the SARS-CoV-2 pandemic on the attack rate of COVID-19 in Canada. The authors describe their simulations of the epidemic, the model parameters, simulations of NPIs, and their outcome measures. This model is an age-stratified, dynamic deterministic compartmental susceptible-exposed-infectious-recovered (SEIR) model.

The model was implemented in R [https://www.r-project.org/] and explored several NPIs, including case detection and isolation; contact tracing and quarantine; and changes to physical distancing as restrictive measures were lifted in May of 2020. The model equation includes compartments for hospitalizations, intensive care unit (ICU) admissions, including those on ventilators and also deaths. Transmission was measured using daily contact rates amongst and within six age groups. The assumptions of the model include:

- asymptomatic infectiousness is equal to that of symptomatic;
- all detected cases are isolated
- detection and isolation occur after the presymptomatic stage for each individual, and quarantining of contacts starts at the latent phase for each individual and covers the entire duration of its infectious period;
- quarantined individuals interact with only one person daily; and
- no births or non-COVID-19-related deaths occur in the population during the projected time.

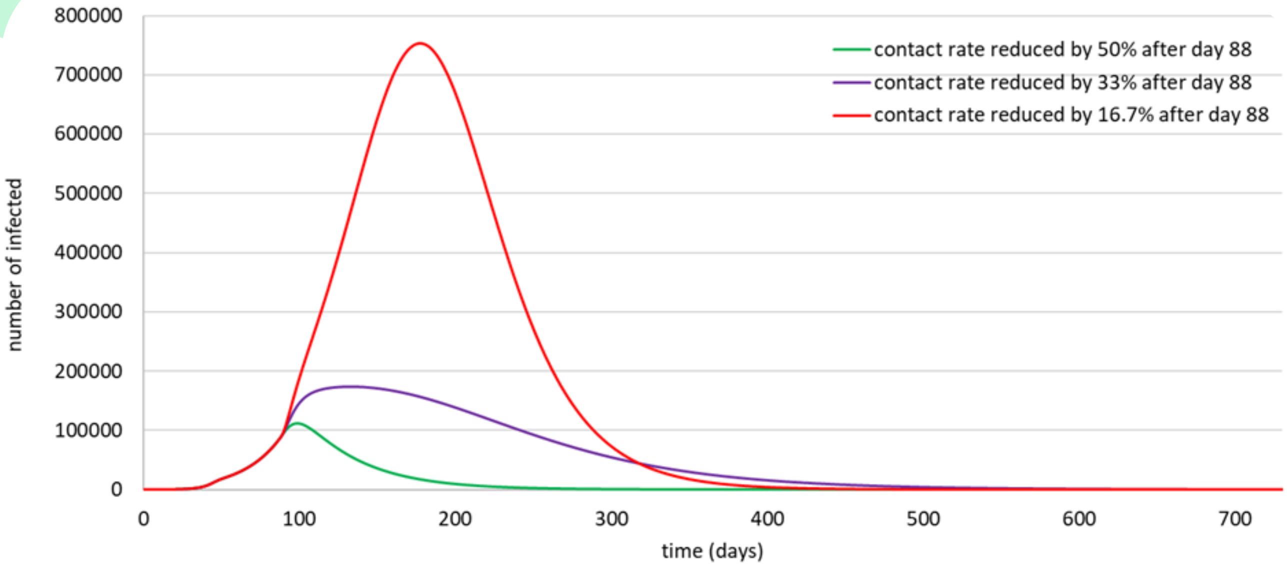
Parameters and initializations of the model assumed community transmission in Canada began February 8, 2020 and parameter values were set according to an extensive review of the literature conducted by PHAC as well as fitting to observed surveillance data for cases in Canada. The study design is for the entire population in Canada and included varying levels of case detection and isolation, contact tracing and quarantining, and physical distancing from days 0 to 88 (May 5) to fit observed cases.

From day 88 (the date of lifting restrictive closures), there were three scenarios for physical distancing: i) contact rates remaining at 50% less than pre-pandemic-19 levels (i.e., restrictive closures not lifted); ii) contact rates increasing to 33% below pre-pandemic-19 levels; and, iii) contact rates increasing to 16.7% below pre-pandemic levels until the end of the simulation. Six levels of case detection/isolation (from 30% to 80% in 10% increments) and six levels of contact tracing/quarantining (from 30% to 80% by 10% increments) were simulated for each of the three physical distancing scenarios, for a total of 108 simulated epidemics.

The primary outcomes of the simulations were the number of infected Canadians over the 730 days and whether the epidemic was controlled during this time (i.e., the number of infected Canadians was under 10% at day 730). Simulations over 730 days were not considered realistic due to the fact that recovered waning immunity was not modelled and individuals did not become susceptible again.

Across simulations, the overall attack rate was found to be significantly worse when physical distancing was relaxed (1.6% -76.6% Canadians infected). The epidemic was controlled approximately 50% of the time when the contact rate was kept at half of pre-pandemic levels from day 88 forward.

Figure 1. Simulation of the epidemic for three scenarios after day 88 (May 4, 2020).



Case detection /isolation at 70%, contact tracing / quarantine at 50% and contact rate reductions of 50, 33 or 16.7% below pre-pandemic levels.
The y-axis includes all individuals in the infectious states—pre-symptomatic, symptomatic (hospitalized or not) and asymptomatic.

As an example, the epidemic was also controlled when 70% of cases were detected and isolated, coupled with 30% of contacts traced, and individuals interacting at half of the pre-pandemic daily contact rate. Successfully detecting and isolating cases was found to be more effective than contact tracing, but maximum efficiency comes from combining both. This work highlights the importance of ensuring a relatively high level of detection/isolation of cases, followed by the tracing/quarantining of potentially infected cases, while maintaining some physical distancing to avoid a resurgence of the epidemic in Canada. For example, the total attack rate was lowest when these measures were effective at 80% of their capacity.

The model results are in accordance with models that are not stratified by age and can be applied nationally and locally. The model accounts for the main disease states, including latent and pre-symptomatic states, as well as the age structure in the Canadian population, which is important given that transmission varies by age. The model assessed case detection level rather than the proportion of asymptomatic cases among all cases, taking into account the current lack of precision on the number of asymptomatic cases, which is a still a challenge for COVID-19 modelling.

As with most mathematical modelling, translating the levels of NPI modelled into the real world is not always easy and can be open to interpretation. While the model uses current best estimates for parameter values, the values may change as knowledge of COVID-19 increases.

Current model (version 15)

Since the submission of the article describing the model, a number of modifications were implemented to either add functionality to the model, or to allow it to better account for more recent understanding of COVID-19 transmission in Canada.

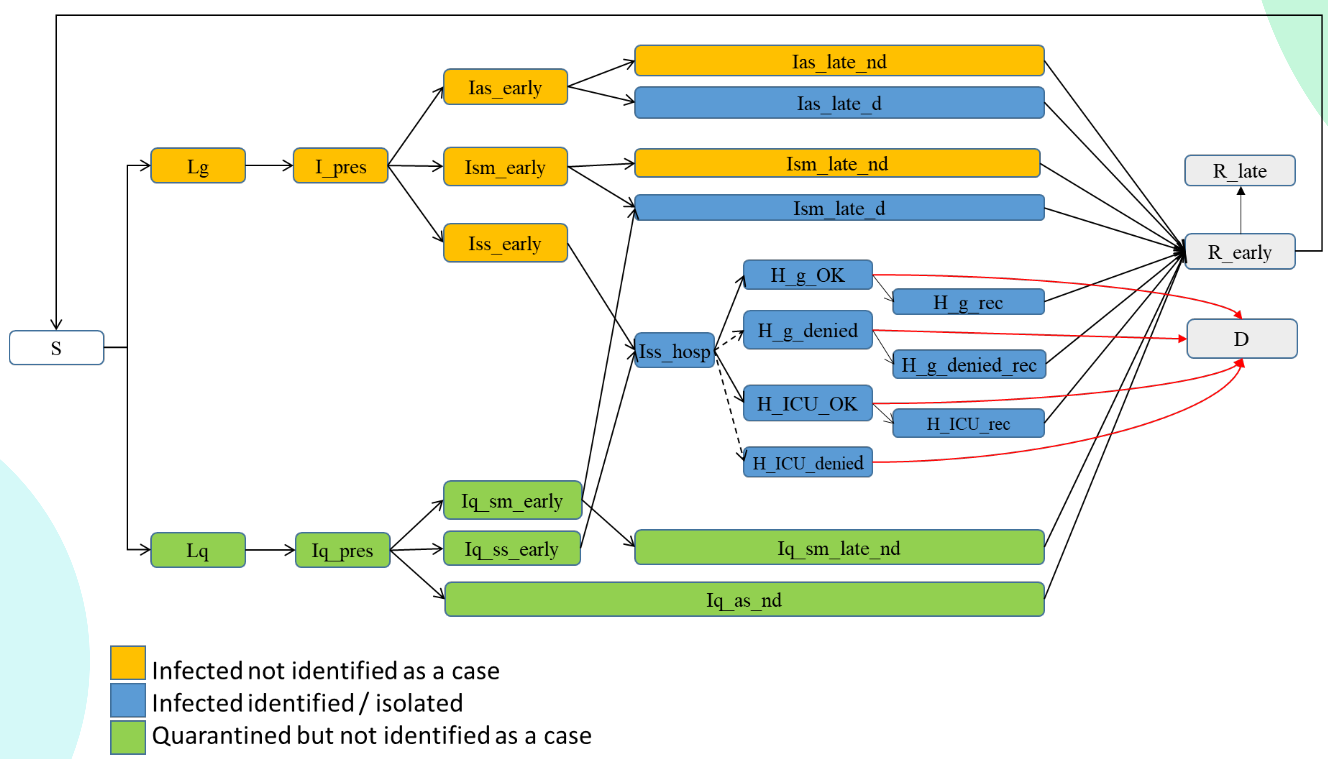
A more refined process of case isolation was implemented to allow for including delays in getting isolated following onset of symptoms or being tested for asymptomatic, mildly symptomatic and severe symptomatic cases, both in the general population and in the quarantined population. This was implemented by dividing the symptomatic phase (or equivalent period of time for asymptomatic) into early and late phases where the early phase is used to account for such delays: this is done in parallel for asymptomatic, mildly symptomatic and severely symptomatic cases.

Changes were also made to the model's hospitalization compartments to allow different duration times to distinguish cases who survive the infection from those who don't. Furthermore, a simplification was performed where cases requiring ventilator support are now included in ICU units.

Finally, the capacity to simulate waning immunity was also incorporated in the model.

The corresponding modified stocks and flows diagram can be seen in the figure below.

Figure 2. Stocks and flow diagram of the PHAC SEIR model



Public Health Agency of Canada

Mathematical modelling was conducted by the Public Health Agency of Canada. This document is a joint production of the Public Health Agency of Canada and the National Collaborating Centre for Infectious Diseases.

National Collaborating Centre for Infectious Diseases
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