Potential Age-Specific Health Impacts from Uncontrolled Spread of the COVID-19 Pandemic on the New Zealand Population Using the CovidSIM Model: Report to the NZ Ministry of Health

Prepared for the Ministry of Health

by
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16 March 2020

https://www.otago.ac.nz/wellington/departments/publichealth/research/heiru/index.html
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NOTE

Although this report was correct at the time of writing, the information it presents may no longer be current because of continuing evolution of the COVID-19 pandemic and our understanding of it. This report was superseded by the final modelling report dated 26 March which used updated parameters.
Unless otherwise indicated, peer review and full consultation with relevant agencies was not always possible in the timeframe available for producing this report.

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Abstract

Aim: To describe potential age-specific health outcomes from the uncontrolled spread of COVID-19 in New Zealand (NZ) using different scenarios.
Methods: We used a SEIR model for modelling the potential impact of COVID-19 (http://covidsim.eu). The Ministry of Health supplied age-specific estimates they wished to have modelled and other modelling parameters were sourced from the literature.
Results: The modelling results suggest that for the less severe scenario (reproduction number [R_0] = 1.5), there would be a total of 92,500 cases needing hospitalisation, 14,400 cases needing ICU admission, 6,480 people requiring ventilators and 8,190 deaths (Table 3). For the more severe R_0 = 2.0 scenario, there would be a total of 124,000 cases needing hospitalisation, 19,400 cases needing ICU admission, 8,690 people requiring ventilators and 10,983 deaths (Table 4). Of the deaths, 87% would be expected to be in the 65+ age-group. The estimated mortality burden from the R_0 = 2.0 scenario at 0.22% of the NZ population, is large, but not unprecedented. That is, it is still less than the 0.8% of the population dying from the 1918 influenza pandemic in NZ.
Conclusions: These large potential adverse health outcomes may justify substantive societal and governmental resources being put into prevention ie, to prevent spread, or to dampen these epidemic curves, or to push them into a subsequent year where disease could be prevented with an available vaccine (as detailed in a previous modelling report supplied on 13 March to the Ministry). Preparing health services for the possibility of containment failing is also likely to help reduce the mortality burden.

Introduction

There is pandemic level spread of the new coronavirus "SARS-Cov-2", causing the disease "COVID-19", with the World Health Organization (WHO) reporting cases in more than 120 countries/territories/areas in mid-March 2020.[1] One approach to informing the potential health burden and relevant control measures for a new pandemic is to study its dynamics using mathematical models. Indeed, recently published mathematical modelling work on COVID-19 has reported that "in most scenarios, highly effective contact tracing and case isolation is enough to control a new outbreak of COVID-19 within 3 months."[2] Other such models have been used to estimate the impact of disease control measures in China.[3 4] But in this particular report we explore

the potential health impact of uncontrolled spread of the COVID-19 pandemic in New Zealand, focusing specifically on potential impacts on different age-groups.

Methods

In this modelling, we took the fairly standard approach of using a deterministic SEIR model i.e., compartments for: susceptible [S], exposed [E], infected [I], and recovered/removed [R]. This model was developed specifically for COVID-19 by a German team of modellers (Prof Martin Eichner et al, see the 13 March 2020 Report to the Ministry of Health). The model is freely available online with a dashboard display to facilitate user interaction (http://covidsim.eu; 14 March version). The details of the parameters, derived variables and differential equations used in the CovidSIM model were appendicised in the previous modelling report to the Ministry (13 March). Table 1 provides the input parameters used in the modelling for this particular report on age-specific impacts.

Table 1: Input parameters for modelling the health impacts for the New Zealand population using the CovidSIM model

Parameter	Value/s used	Further details
Population size	4,951,500	New Zealand (NZ) population as per December 2019.[5]
Number of infected cases arriving in the country	5 per day	To model uncontrolled spread in the NZ setting, the simulation was "seeded" with infected cases arriving in the country from overseas at the level of 5 per day, beginning on 1 April 2020.
Infections which will lead to sickness	82%	We used an estimate calculated from the well studied outbreak on the Diamond Princess cruise ship that 18% of infected (test positive) individuals did not develop symptoms.[6] More specifically the estimate was 17.9% (95% credible interval (CrI): 15.5–20.2%).
Sick patients needing hospitalisation	3.0% (with variation by age-group, see Table 2)	We used this 3.0% estimate as supplied by the NZ Ministry of Health. Nevertheless, we note that this value consistent with the lower estimate out of three being reportedly used, or considered for, modelling in the United States (3%, 5% and 12%).[7] Nevertheless, there is quite high uncertainty around this figure due to the likely under-diagnosis of mild cases in many settings (impacting the size of the denominator). It also may vary between countries given the use of hospital facilities to isolate mild cases (e.g., where other forms of isolation for mild cases are not available or suitable). These factors may be relevant in a large Chinese study,[8] where 13.8% of cases were classified as "severe" and 4.7% were classified as "critical" (4.7%), i.e., a total of 18.5% likely to need hospitalisation. More specifically, in this study of 44,672 confirmed cases: "Severe was characterized by dyspnea, respiratory frequency $\geqslant$30/minute, blood oxygen saturation $\leqslant$ 93%, PaO_2/FiO_2 ratio <300, and/or lung infiltrates >50% within 24–48 hours. Critical cases were those that exhibited respiratory failure, septic shock, and/or multiple organ dysfunction/failure."
Hospitalised cases needing intensive care (ICU)	15.0% (with variation by age-group, see Table 2)	We used this 15.0% estimate as supplied by the NZ Ministry of Health. It is a somewhat less than the previous value we have used in modelling work for the Ministry that we derived from the Chinese study in the above row of (i.e., 4.7%/(13.8% + 4.7%) = 25.4%). This is similar to the Chinese case series reported by Wang et al at 26.1%.[9] Nevertheless, it is higher than reported in a smaller case series from Singapore at 11% (2/18).[10]
Cases in ICU requiring ventilation	45% (with variation by age-group, see	We used this 15.0% estimate as supplied by the NZ Ministry of Health.

Parameter	Value/s used	Further details
	Table 2)	
Symptomatic patients die from the disease	0.25%	We used this 0.25% estimate as supplied by the NZ Ministry of Health. For comparison we note that the WHO has reported an infection fatality risk for COVID-19 of 0.3% to 1% (based on 3 publications).[11] Also of note is an estimate for China outside of Hubei Province when adjusted for the delay in reporting death i.e., 0.81 (95%CI: 0.67 to 0.98).[12] This "China outside of Hubei" estimate is also very similar to an earlier estimate using a CFR (also adjusted for the time delay in deaths) for China outside of Hubei Province (i.e., 0.9%; 95% credible interval: 0.6-1.3%).[13]
Basic reproduction number (R_0)	1.5, 2.0	We used these two values in separate scenarios as requested by the NZ Ministry of Health. Of note is that on 6 March 2020, the WHO reported that this number was likely to be in the range of 2.0 to 2.5.[14] Also of note is that an earlier review of 12 studies[15] suggested estimates that "ranged from 1.4 to 6.49, with a mean of 3.28, a median of 2.79 and interquartile range (IQR) of 1.16."… "In more recent studies, R_0 seems to have stabilized at around 2–3."
Relative contagiousness in the prodromal period	50%	There is no reported value in the literature so we used this default value in CovidSIM, which has some biological plausibility. That is while there is similarity in viral loads between asymptomatic and symptomatic COVID-19 patients,[16] it would be expected that those who are fully symptomatic (with a cough etc) would be more likely to transmit infection.
Durations	Default values	We used the default values in CovidSIM. That is average duration of the latency period = 4 days (as per Read et al[17]); average duration of the prodromal period = 1 day; average duration of the symptomatic period = 10 days. We note that the WHO-China Joint Mission Report stated that: "the median time from onset to clinical recovery for mild cases is approximately 2 weeks and is 3-6 weeks for patients with severe or critical disease."[18] It also stated that the average incubation period was 5-6 days (range 1-14 days).[18]
Seasonality effect	Variation in R_0 of 25% (sinusoidal variation)	Winter conditions are known to accelerate transmission of influenza and also the other coronaviruses which cause cold-like symptoms.[19] Indeed, enveloped viruses show strong seasonality with winter peaks,[20] and SARS-Cov-2 is an enveloped virus. Even though there are many uncertainties relating to seasonality and this novel coronavirus,[21] it seems prudent to assume some seasonal fluctuation so we set this at 25% higher in winter and 25% lower in summer. The day when the seasonal R_0 reached its maximum was set at day 106 of the simulation (ie, we assumed that uncontrolled spread started in NZ on 1 April 2020). This gave a mid-winter peak on 15 July in NZ (ie, after 106 days).
Interventions		
General contact reduction	NA	No interventions modelled.
Case isolation	NA	No interventions modelled.

Table 2: Age-specific parameters for modelling health impacts for the New Zealand population from the uncontrolled spread of the COVID-19 pandemic

Age-group (years)	Census 2018 population	Population scaled to 2020	Proportion of symptomatic cases hospitalised*	Proportion of hospitalised cases admitted to ICUs*	Proportion of ICU cases requiring a ventilator*	Proportion of symptomatic cases dying (case fatality risk)*
0-4	294,921	310,718	1.25%	15.0%	35.0%	0.01%
5-17	809,576	852,940	0.50%	20.0%	30.0%	0.0075%
18-49	2,007,859	2,115,407	1.25%	15.0%	45.0%	0.045%
50-64	872,238	918,958	1.75%	20.0%	50.0%	0.10%
65+	715,170	753,477	16.0%	15.0%	45.0%	1.75%
Overall			**3.00%**	**15.0%**	**45.0%**	**0.25%**
Total	**4,699,764**	**4,951,500**				

* Estimates supplied to the authors by the Ministry of Health.

Results

Figure 1 shows the epidemic curves for the two different reproduction number (R_0) values. The built-in seasonality adjustment has slightly moved the peaks of these curves forward in time (due to accelerated transmission during the NZ winter).

The modelling results suggest that for the less severe scenario (reproduction number $R_0 = 1.5$), there would be a total of 92,500 cases needing hospitalisation, 14,400 cases needing ICU admission, 6,480 people requiring ventilators and 8,190 deaths (Table 3). For the more severe $R_0 = 2.0$ scenario, there would be a total of 124,000 cases needing hospitalisation, 19,400 cases needing ICU admission, 8,690 people requiring ventilators and 10,983 deaths (Table 4). Of the deaths, 87% would be expected to be in the 65+ age-group (Table 4, Figure 2).

Figure 1: Epidemic curves for the spread of COVID-19 in New Zealand ($R_0 = 1.5$ and $R_0 = 2.0$ and as per parameters in Table 1) assuming no changes in human behaviour or interventions (ie, which is unrealistic but is assumed here to demonstrate uncontrolled epidemic patterns)

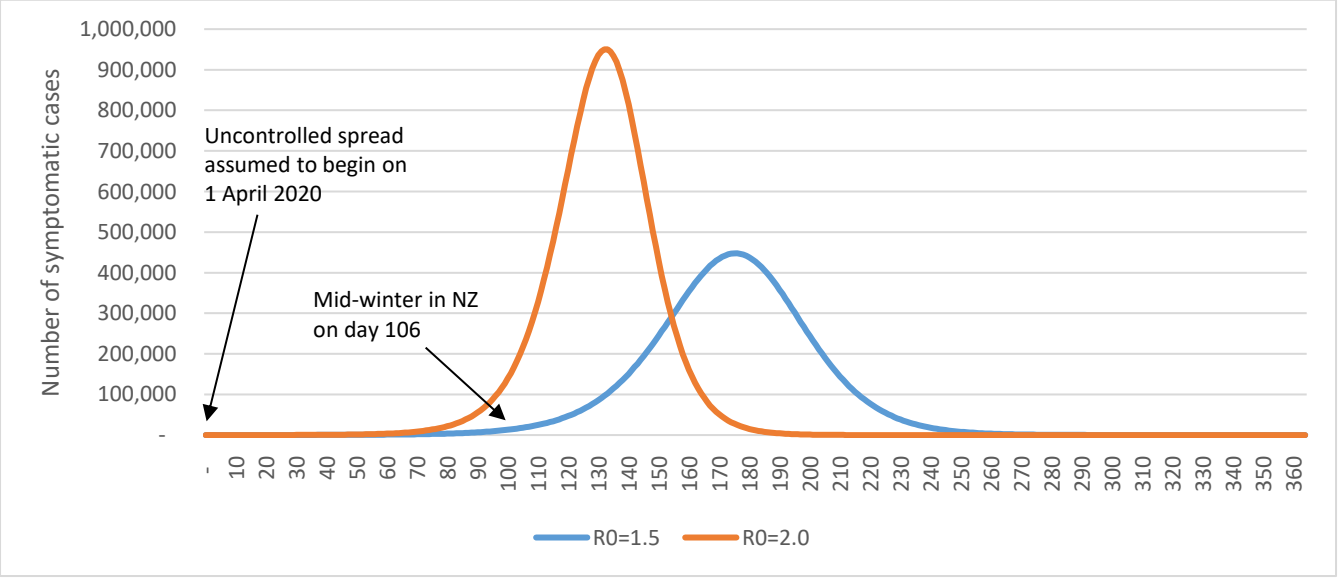


Table 3: Age-specific results for the R_0 = 1.5 scenario for the hypothetical uncontrolled spread of the COVID-19 pandemic in New Zealand

Age-group (years)	Symptomatic cases (number)*	Symptomatic cases hospitalised	Hospitalised cases needing ICU	ICU cases requiring a ventilator	Deaths	% of all deaths
0-4	167,928	2,099	315	110	17	0.2%
5-17	460,973	2,305	461	138	35	0.4%
18-49	1,143,275	14,291	2,144	965	514	6.3%
50-64	496,652	8,691	1,738	869	497	6.1%
65+	407,218	65,155	9,773	4,398	7,126	87.0%
Total	**2,676,046**	**92,541**	**14,431**	**6,480**	**8,189**	**100.0%**
% of NZ population	54.0%	1.9%	0.29%	0.13%	0.17%	

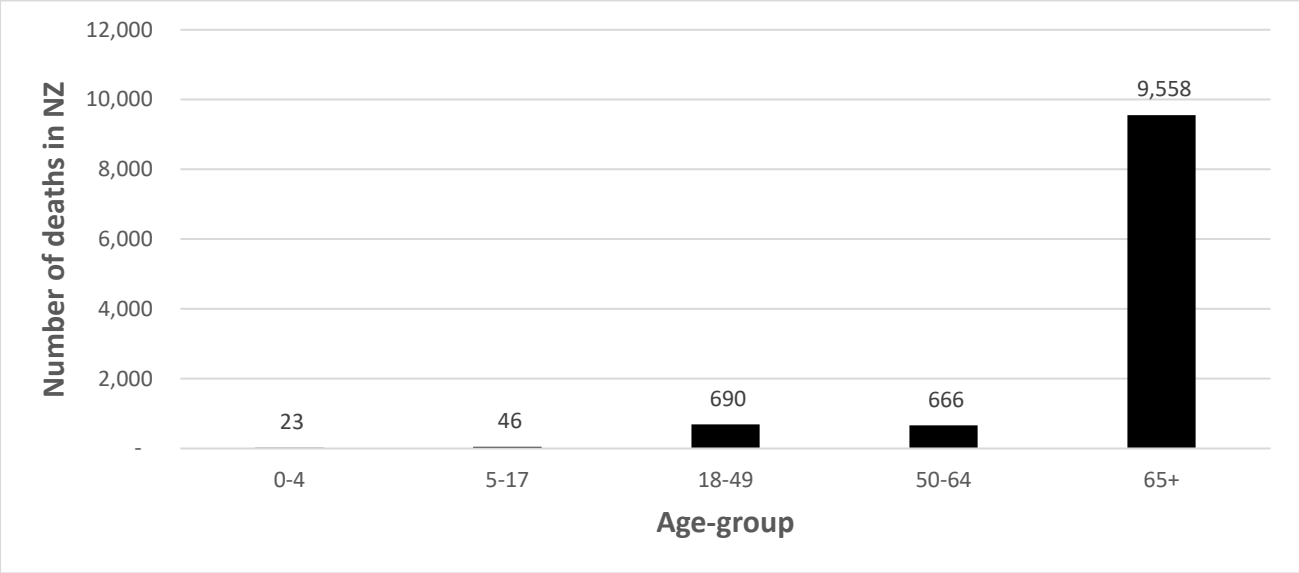
* The total proportion of symptomatic cases was derived from CovidSIM output. The subsequent partitioning reflects the NZ population structure and the age-specific values provided by the NZ Ministry of Health. We assumed there was no differential in age-specific risk of infection, however, it is possible that transmission may be higher in children (as it is with influenza – another respiratory virus).

Table 4: Age-specific results for the R_0 = 2.0 scenario for the hypothetical uncontrolled spread of the COVID-19 pandemic in New Zealand

Age-group (years)	Symptomatic cases (number)*	Symptomatic cases hospitalised	Hospitalised cases needing ICU	ICU cases requiring a ventilator	Deaths	% of all deaths
0-4	225,225	2,815	422	148	23	0.2%
5-17	618,256	3,091	618	185	46	0.4%
18-49	1,533,358	19,167	2,875	1,294	690	6.3%
50-64	666,109	11,657	2,331	1,166	666	6.1%
65+	546,160	87,386	13,108	5,899	9,558	87.0%
Total	**3,589,108**	**124,116**	**19,355**	**8,691**	**10,983**	**100.0%**
% of NZ population	72.5%	2.5%	0.39%	0.18%	0.22%	

* The total proportion of symptomatic cases was derived from CovidSIM output. The subsequent partitioning reflects the NZ population structure and the age-specific values provided by the NZ Ministry of Health. We assumed there was no differential in age-specific risk of infection, however, it is possible that transmission may be higher in children (as it is with influenza – another respiratory virus).

Figure 2: Estimated age-distribution of deaths from the uncontrolled spread of the COVID-19 pandemic in New Zealand (R_0 = 2.0 scenario)



Discussion

These modelling results suggest large health impacts from uncontrolled pandemic spread in New Zealand, especially for the R_0 = 2.0 scenario. The impact would be especially felt in the 65+ age-group, where 87% of the deaths would be expected to occur. Also, as we detailed in our previous report to the Ministry (13 March), past evidence from pandemics in New Zealand[22] [23] indicates relatively higher health burdens for Māori and Pacific peoples are likely.

The estimated mortality burden from the R_0 = 2.0 scenario at 0.22% of the New Zealand population (Table 4), is large, but not unprecedented. That is, it would still be less than the 0.8% of the population dying from the 1918 influenza pandemic in New Zealand (ie, 9000 deaths[24] out of 1.149 million people at that time).

To put the demand on ICU services into context, we note that the Wellington ICU currently treats about 1700 patients each year.[25] If it is serving around 10% of the NZ population then for the R_0 = 2.0 scenario (19,355 cases, Table 4), it may have to cope with 1.1 times its normal annual demand from COVID-19 cases alone (1936/1700=1.14), but all in the space of a few months.

All modelling work has limitations – as detailed in our previous report to the Ministry (13 March). In particular, it is very likely that the age-specific specific values used in this analysis will be further revised in the near future as more research on COVID-19 is published. Furthermore, the case fatality risk values could also substantially increase if hospitals and ICUs became overloaded and can no longer provide adequate care. Triage processes within overloaded hospitals may also result in greater attention to younger people – and so case fatality rates for older people may disproportionately increase.

Potential implications

The potentially high health burden suggested by this modelling work may support very intensive control measures, especially given the Chinese evidence that these can be successful (ie, as per the

WHO-China Joint Mission Report[18]). While it is an open question around the generalisability of all of these approaches to other countries,[26] there is also evidence outside of mainland China from Singapore, Hong Kong and Taiwan that intensive containment against the spread of SARS-Cov-2 can be successful.[27]

But if containment fails in New Zealand, it is important to also consider how to reduce the load on the health system – which if overloaded may fail to prevent severe outcomes such as death. Potential options are:

- Continue with major investment in prevention and intense containment to slow disease spread (eg, identification and isolation/quarantine of cases and contacts; promoting hygiene measures and social distancing measures). If strong enough, these measures may still allow for epidemic peak suppression until a vaccine becomes available.
- Make rapid and major investment in website-based educational information for home care for mild/moderately severe cases and capacity for online consultations with health workers (to reduce the demand on the Healthline, other primary care services and hospital services). This transition to online medical consultations was successfully achieved in China in January/February 2020.
- Start now to introduce a programme to protect highly vulnerable groups from infection. The data from China shows older age-groups and those with co-morbidities are at relatively much greater risk of death than younger and healthier groups.[8] Previous New Zealand research on influenza has also identified markedly higher rates of hospitalisation for those living with long-term conditions.[28] If COVID-19 follows the same patterns as previous pandemics, we would expect a relatively high and heavily unequal hospitalisation and mortality burden on Māori and Pacific populations (see our 13 March report). Such a programme could aim to ensure vulnerable people have the option of moving to, or living in, "safe havens" for the duration of the pandemic, or for periods when it is at its most intense. Options could include a range of scales from: specific measures for those living in their own homes and well managed institutions, to voluntary relocation to specific places that can be protected.
- Ensure rapid and major investment in planning by hospitals and ICUs (eg, updating triage processes and planning around when to suspend elective surgery and annual leave for public sector health workers etc). For example, 40% of admissions to the ICU in Wellington are following elective major surgery.[25] Indeed, media reports already indicate that DHBs are preparing in this way.

Many of these interventions require substantial resources and it will be up to political leaders to balance the potential health benefits with the various downsides in terms of intervention costs and any psychological, social and economic costs (eg, from closing schools, closing entertainment venues, restricting mass transit and restricting internal travel).

Acknowledgements: The New Zealand based team members thank the New Zealand Ministry of Health for funding support and for providing feedback on earlier modelling work. Nevertheless, we note that this work is that of the named authors alone and does not necessarily represent the views of the New Zealand Ministry of Health or any other parties. We also thank our German colleagues (Prof Martin Eichner, Stefan Brockmann, Dr Markus Schwehm) who developed CovidSIM and worked with us to refine its functionality. Prof Wilson is supported by the Health Research Council and Ministry of Business Innovation and Employment (MBIE) funding of the BODE^3 Programme.

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