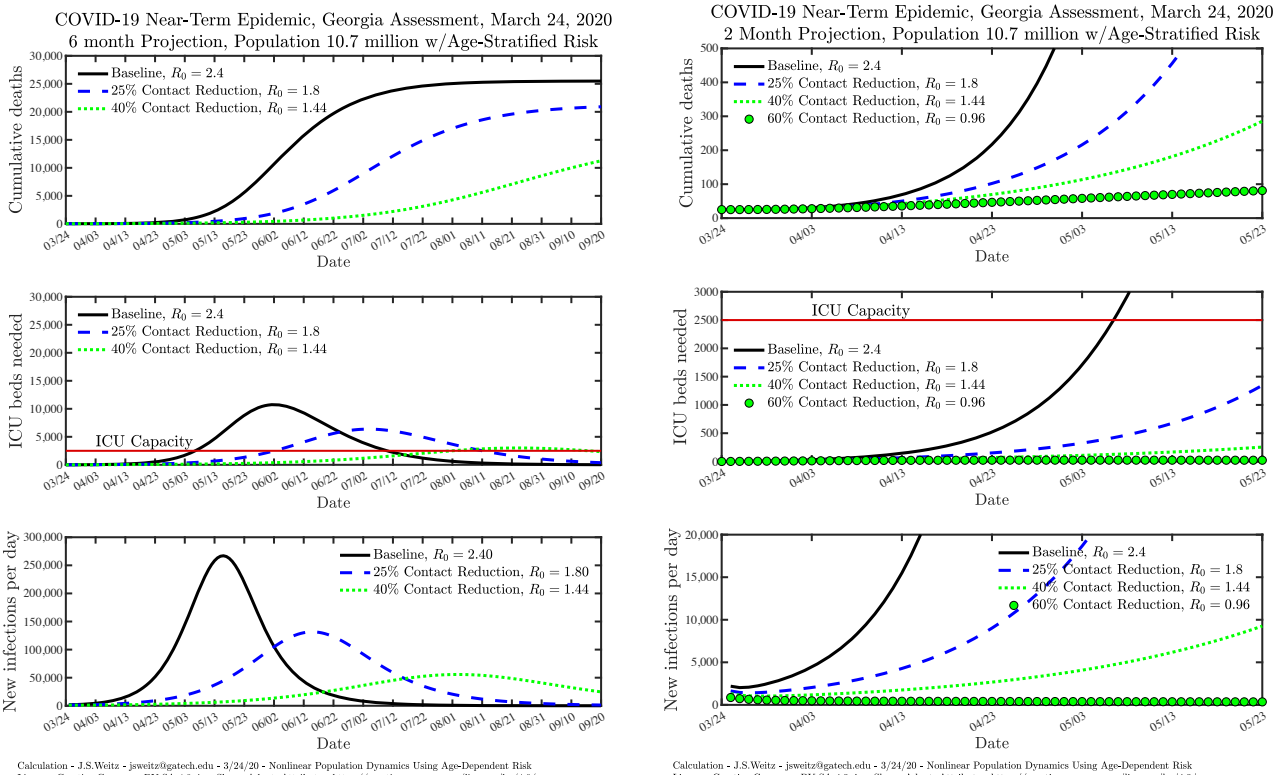
COVID-19 Epidemic Risk Assessment for Georgia, March 24, 2020

Joshua S. Weitz[1, 2, *]

[1] *School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA, USA*
[2] *School of Physics, Georgia Institute of Technology, Atlanta, GA, USA*

(Dated: March 24, 2020)

Summary Findings:
A population model of COVID-19 was developed to include transmission and progress of disease, including estimates of hospitalization, acute ICU beds needed, and total fatalities – following standard approaches to compartmental epidemic models. The model was parameterized with epidemiological characteristics of SARS-CoV-2 along with US Census demographic data for Georgia. As shown in the summary figure below, the expected outcomes for business-as-usual or nearby scenarios (with 25% or 40% reduction in contacts) all lead to more than 10,000 total deaths in a 6 month horizon and an excess of demand for ICU beds in the state. **The public health risk for inaction or insufficient control measures are significant. However, reduction by ≈ 60% (or more) of contacts could lead to control of cases, both in the near term (right panel) and long-term**. Short-term severe restrictions could buy time for implementation of viral testing via PCR to prevent transmission (at scale, not just to confirm infections), serology (to identify recovered individuals), surveys to identify potential clusters, isolation, and treatment without overloading capacity.



*Electronic address: jsweitz@gatech.edu; URL: http://ecotheory.biology.gatech.edu

Typeset by REVTEX

Mathematical Model of COVID-19 – Baseline Case and Comparisons

The population model of COVID-19 includes susceptible S, exposed E, infectious asymptomatically I_a, infectious symptomatically I_s, and recovered R individuals who are free to move, without restrictions in a 'business as usual' scenario. A subset of symptomatic cases will require hospital care, which we further divide into subacute I_{hsub}, and critical/acute (i.e., requiring ICU intervention) I_{hcri} cases. We assume that a substantial fraction of critical cases will die. The model considers these 8 classes of individuals, further stratified by age a, in 10 categories, from 0-9; 10-19; 20-19, and so on, until 90-99, and avoids the inclusion of birth and death processes (for simplicity). The total number of asymptomatic and symptomatic infected cases are $I_{tot,a}$ and $I_{tot,s}$ respectively. The equations retain age structure for all categories.

$$\dot{S}(a) = -\beta_a S(a) I_{tot,a} - \beta_s S(a) I_{tot,s} \quad (1)$$

$$\dot{E}(a) = \beta_a S(a) I_{tot,a} + \beta_s S(a) I_{tot,s} - \gamma_e E(a) \quad (2)$$

$$\dot{I}_a(a) = p\gamma_e E(a) - \gamma_a I_a(a) \quad (3)$$

$$\dot{I}_s(a) = (1-p)\gamma_e E(a) - \gamma_s I_s(a) \quad (4)$$

$$\dot{I}_{hsub}(a) = h(1-\xi)\gamma_s I_s(a) - \gamma_h I_{hsub}(a) \quad (5)$$

$$\dot{I}_{hcri}(a) = h\xi\gamma_s I_s(a) - \gamma_h I_{hcri}(a) \quad (6)$$

$$\dot{R}(a) = \gamma_a I_a(a) + (1-h)\gamma_s I_s(a) + \gamma_h I_{hsub}(a) + (1-\mu)\gamma_h I_{hcri}(a) \quad (7)$$

$$\dot{D}(a) = \mu\gamma_h I_{hcri}(a) \quad (8)$$

The basic reproduction number of this model is

$$\mathcal{R}_0 = p\mathcal{R}_a + (1-p)\mathcal{R}_s \quad (9)$$

where $\mathcal{R}_a = \beta_a/\gamma_a$ and $\mathcal{R}_s = \beta_a/\gamma_s$. Technically this model has 80 ODE-s (all code available via github; of note, the code itself is modifiable to include age-structured asymptomatic fraction, as suggested by Leung and colleagues, Nature Medicine, 2020). The baseline epidemiological parameters, age stratified risk, and population structure are listed in tables at the end of this manuscript (adapted from [1–4]).

We use the baseline epidemiological parameters and start all outbreaks with 8000 infections and 25 deaths, with 500 symptomatic and 7500 asymptomatic individuals out of a population of approximately 10.7 million. We consider outbreak scenarios that differ in transmission rates assuming reduction in social contact (see table at end) by 25% and 40%. Neither of these 'mitigation' strategies is enough to halt the epidemic. The baseline results are broadly consistent with the more complex Imperial College London Model, with the majority of deaths centered around those ages 60 and above, despite the lower fraction of individuals in those ranges.

Acknowledgments and Code: JSW thanks C. Andris for sharing census data, K. Carden for sharing ICU data (originally from 'Kaiser Health News analysis of hospital cost reports filed to the Centers for Medicare and Medicaid Services' - khn.org), as well as J. Dushoff, K. Levy and the Weitz group for feedback. Mistakes are the fault of the author solely. All code is available at: `https://github.com/jsweitz/covid-19-ga-summer-2020`.

1 Park SW, Cornforth DM, Dushoff J, Weitz JS (2020) The time scale of asymptomatic transmission affects estimates of epidemic potential in the covid-19 outbreak. *medRxiv*.

2 Wu JT, Leung K, Leung GM (2020) Nowcasting and forecasting the potential domestic and international spread of the 2019-ncov outbreak originating in wuhan, china: a modelling study. *The Lancet* 395:689–697.

3 Li R, et al. (2020) Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (sars-cov2). *Science*.

4 Wu J, Leung K, Bushman M, et al. (2020) Estimating clinical severity of covid-19 from the transmission dynamics in wuhan, china. *Nature Medicine*.

Assumptions for Age-Structured COVID-19 Model

Parameter	Meaning	Value
β_a	Asymp transmission	0.3/day (base), 0.225/day (25%) 0.18/day (40%), 0.12/day (60%)
β_s	Symp transmission	0.6/day (base), 0.45/day (25%), 0.36/day (40%), 0.24/day (60%)
$1/\gamma_e$	Mean exposed period	2 days
$1/\gamma_a$	Mean asymp period	4 days
$1/\gamma_s$	Mean symp period	10 days
$1/\gamma_h$	Mean hospital period	10 days
p	Fraction asymptomatic	0.75
$\mathcal{R}_0$	Basic reproduction number	2.4 (base), 1.8 (25%) and 1.44 (40%)

TABLE I: Epidemiological characteristics – general findings are robust to variation, but time-scales of spread are modulated by speed of processes.

Age	Hospital Fraction	ICU (given hospitalization) Fraction
0-9	0.001	0.05
10-19	0.003	0.05
20-29	0.012	0.05
30-39	0.032	0.05
40-49	0.049	0.063
50-59	0.102	0.122
60-69	0.166	0.274
70-79	0.243	0.432
80-89	0.273	0.709
90-99	0.273	0.709

TABLE II: Age-stratified risk for COVID-19. Of note, the model assumes that 50% of ICU cases die.

Age	Fraction of Population
0-9	0.13
10-19	0.14
20-29	0.14
30-39	0.13
40-49	0.13
50-59	0.13
60-69	0.10
70-79	0.06
80-89	0.03
90-99	0.01

TABLE III: Assumed age structure of the GA population based on the 2018 US census with population of approximately 10.7 million individuals.