Mobility Restrictions For The Control of COVID-19 Pandemic

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Abstract

Objective

- Evaluate the prediction accuracy of the SEIR model;
- Estimate the most effective mobility restriction parameter for outbreak control through logistic regression models.

Study Design and Setting

- Basic reproduction number (R0) and the infectious periods were calculated by mathematical constrained optimization based on data collcted until April 11th.
- Community Mobility Reports from Google Maps (<https://www.google.com/covid19/mobility>) provided mobility changes data.
- The impact of each mobility component was calculated by logistic regression models.
- COVID-19 control was defined by SEIR model R0<1.0 in a country.

Results

- An increase of 50% in mobility trends for places of residence implicated a 99% chance of outbreak control.
- SEIR predictions were accurate.

Introduction

In December 2009, a cluster of patients with pneumonia was reported in the city of Wuhan, capital of Hubei province, China, caused by a novel coronavirus, named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

The modeling of infectious diseases can be done by compartmental mathematical models such as SIR (susceptible-infected-recovered), SEIR (susceptible-exposed-infected-recovered), SIS (susceptible-infected-susceptible), MSIR (maternally derived immunity-susceptible-infected-recovered). The objective of the study was to evaluate the precision of SEIR model, and efficacy of different community mobility restriction parameters in controlling COVID-19 outbreak.

The Community Mobility Reports from Google Maps® aim to provide insights into what has changed in response to policies aimed at combating COVID-19 (<https://www.google.com/covid19/mobility/>). This data is retrieved from users mobile phone location tracking, obtained with previous user consent.

The Mobility Report from Google Maps® was used to measure adherence to non-pharmacological intervention (Google LLC "Google COVID-19 Community Mobility Reports").

Methodology

Four parameters of the SEIR model were obtained by international experiences: the incubation period=3.7 days, the proportion of critical cases=0.0511, the overall case-fatality rate=0.02311, and the estimated proportion of asymptomatic patients with COVID-19=0.1812. These values can be modified for a specific region.

A Solver from Microsoft Excel ® or NEOS Server were used for finding numerically minimum of a function Z, which represents the sum of squared errors between each new case of COVID-19 observed in one day, and the cases predicted by the SEIR model.

$$Minimize\ Z = \sum_{i=1}^{D} (I_i - \hat{I}_i)^2$$

Subject to

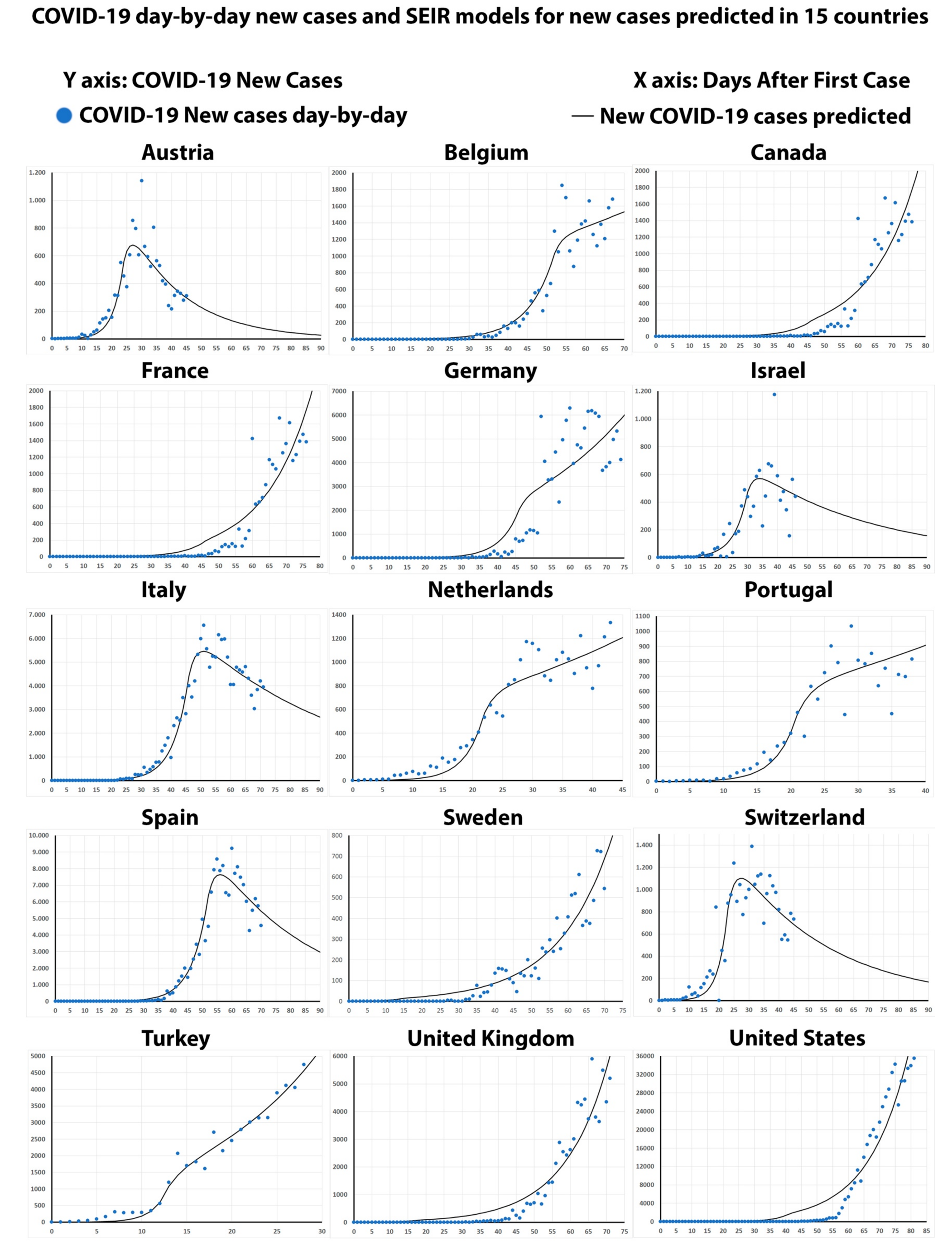
- T_phase_I≤D
- 0.5≤R0_phase_I≤20
- 2≤T_infectious_phase_I≤14
- T_phase_II≤T_phase_I
- 0.5≤R0_phase_II≤20
- 2≤T_infectious_phase_II≤14
- 0.5≤R0_phase_III≤20
- 2≤T_infectious_phase_III≤14

In which:

- I_i = number of COVID-19 new cases observed in a city, state or country during the day i;
- $\hat{I}_i$ = number of COVID-19 new cases predicted by the model in the day i;
- D = total days of the epidemic in a city, state or country;

Results

COVID-19 day-by-day new cases and SEIR models for new cases predicted in 15 countries

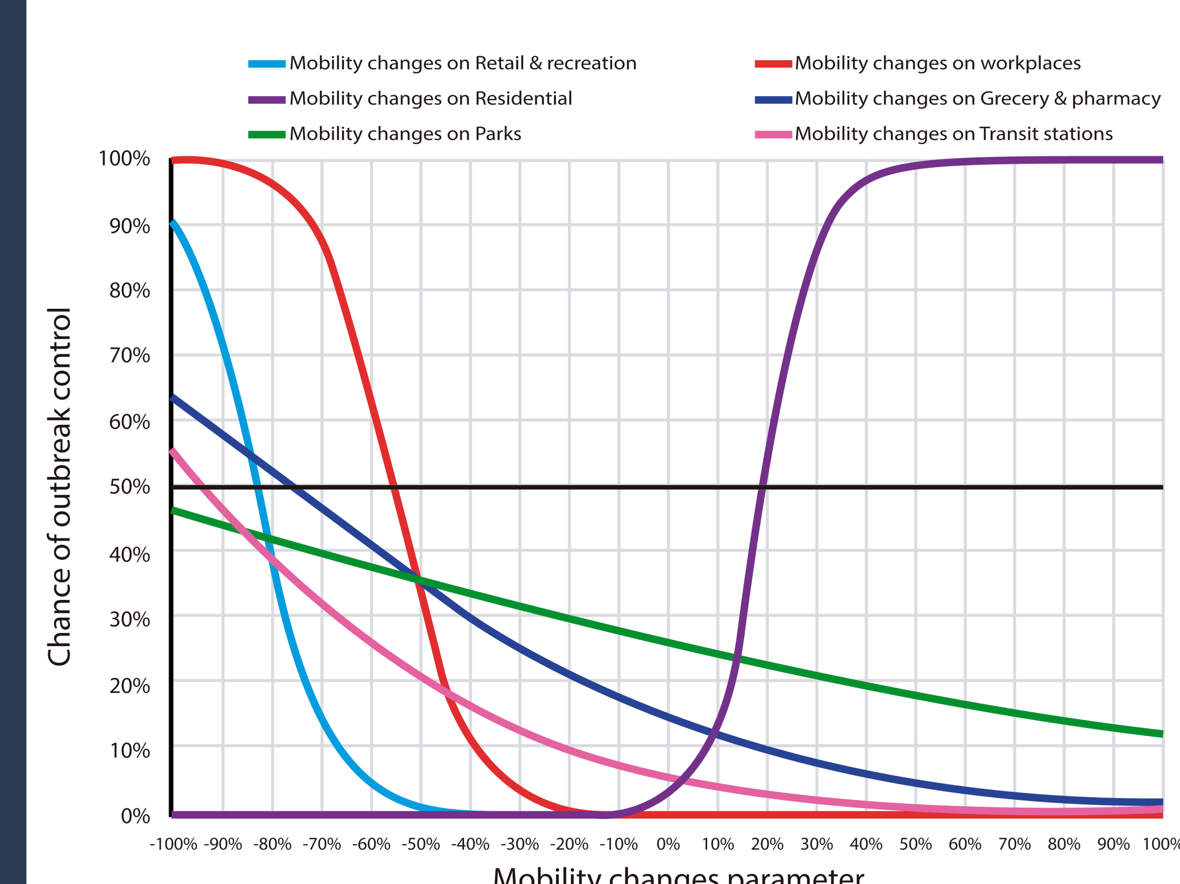


The previous graphs compares SEIR prediction models (line) with COVID-19 new cases reported by official authorities in each country (blue dots).

Six logistic regression models were built for each Google Maps® mobility parameter. The percentage of mobility changes in each country was the exposure variable for the logistic regression modeling.

Mobility Changes Parameters		Logistic regression unstandardized coefficients		Minimum mobility restrictions for the COVID-19 control	
		Constant	Logistic coefficient	Percent	Chance of outbreak control
Retail & recreation	Restaurants, cafes, shopping centers, theme parks, museums, libraries, and movie theaters.	-11.127	-13.4	-100%	91%
Grocery & pharmacy	Grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies.	-1.720	-2,3	-100%	64%
Parks	National parks, public beaches, marinas, dog parks, plazas, and public gardens.	-1.048	-0.9	-100%	46%
Transit stations	Public transport hubs such as subway, bus, and train stations.	-2.774	-3,0	-100%	56%
Workplaces	Offices, financial institutions.	-7.258	-13.2	-72%	90%
Residential	Residential areas.	-3.779	17.7	+34%	90%

The graph bellow demonstrates chance of outbreak control versus mobility changes parameter percentage, based on logistic regression. The negative values implicate an efflux of people, whereas the positive values implicates an influx. Notice that an influx of approximately 20% mobility change on Residential implicates in a 50% chance of outbreak control.



Conclusion

This study is based on a mathematical modeling which, in spite of being subject to limitations, can foretell COVID-19 cases in a region. The analysis was not performed by a statistical modeling process, but rather by a numerical perspective.

A 50% rate of social isolation at home is estimated to be considered sufficient to control COVID-19 epidemic.

Residential mobility restriction presented itself as the most effective measure for the least amount of effort, considering an increase of 50% in the mobility trends for places of residence has a 99% chance of outbreak control.

It is speculated that residency isolation would indirectly reduce the total number of individuals in public places. The degree to which mobility restrictions increase or decrease the overall epidemic size depends on the level of risk in each community and the characteristics of the disease15.

More research is required in order to estimate the optimal balance between mobility restriction, outbreak control, economy, and freedom of movement.

Acknowledgements

unibh
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