Drivers of differential COVID-19 spread and response to interventions in minority populations

Uri Obolski, Assistant Professor, School of Public Health and Porter School of the Environment and Earth Sciences, Tel Aviv University

Jaline Gerardin, Assistant Professor, Department of Preventive Medicine and (by courtesy) Industrial Engineering and Management Sciences, Northwestern University

Daniel Nevo, Senior Lecturer, Department of Statistics and Operations Research, Tel Aviv University

This collaboration united existing teams at Tel Aviv University (Professors Obolski and Nevo) and Northwestern (Professor Gerardin) that had been modeling COVID-19 transmission dynamics used to advise local policymakers. With the Northwestern team's model optimized for fast, flexible examinations of data in Illinois, and the Tel Aviv team's suited for detailed, microscale questions, the teams worked together to improve and expand their models to take on new projects. Modeling the differences in how the disease spreads in minority populations and its implications for effective interventions to contain the epidemic was of particular interest.

Both teams opted to refine their existing models using data and expertise from their new collaborators. The teams met regularly to discuss ideas and project progress. The NU team supplied the TAU team with Chicago ZIP-level data on demographic structure, COVID-19 trajectories, and vaccination rates, and the TAU team explored instantiating their individual-based model on Chicago as an extension of their Israeli settings. The NU team explored using the TAU team's model as a framework for testing the impact of biased surveillance systems on assessments of epidemic growth.

For the Northwestern team, the collaboration informed the development and improvement of three major COVID modeling projects. Having originally developed individual SARS-CoV-2 transmission models for 11 Illinois sub-regions, the team's first project was to improve the accuracy and usability of their existing models. As part of ongoing fit-improvement for their models, the team successfully developed and incorporated a trace selection algorithm. Model structure was expanded to include the ability to account for the effects of vaccinations and additional variants on the spread of the virus. The team also developed better software tools to enable more flexible scenario and Illinois region management, replicable parameter sampling, and the implementation of synthetic sentinel surveillance. This platform was used for a 10-weekundergraduate student projection evaluating outpatient sentinel surveillance performance in Chicago during the October 2020 COVID-19 wave. They created a prototype for routine, ongoing sentinel surveillance of outpatient symptomatic individuals, coupled with a decision-making evaluation and, if criteria are met, a triggered response. The prototype is now being extended to explore the impact of surveillance quality, decision criteria, and speed of action on hospitalizations and deaths averted.

The Northwestern team also evaluated a pair of novel surveillance systems for their efficacy in predicting COVID-19 transmission patters ahead of current state metrics. Data from birthing hospitals testing people entering labor and delivery ultimately did not prove predictive of larger transmission trends, data from community-based diagnostic testing sites did anticipate COVID-19 hospital admissions and emergency department visits by 7 days. The team integrated these findings, as well as the costs of piloting, implementing, and maintaining these programs, into its sentinel surveillance prototype, mentioned above, providing local authorities with greater tools for managing their resources effectively.

Finally, the NU team conducted a descriptive analysis of racial and ethnic disparities in COVID-19in Illinois. In 2020, Black and Hispanic/Latinx communities throughout the United States, including the state of Illinois, experienced disproportionately high rates of COVID-19 cases and deaths. While public health officials in Illinois implemented targeted programs to reduce these disparities, the team's analysis of the relative risks of COVID-19 cases and deaths for Black and Hispanic/Latinx vs. White residents, stratified by age group and epidemic interval, were merely reduced rather than removed. Among other findings, 79.3% and 86.7% of disparities in deaths among Black and Hispanic/Latinx populations, respectively, were attributable to differences in age-adjusted incidence compared to White populations rather than differences in case fatality ratios. The team therefore advocates that studies and policies aimed at reducing inequalities in disease exposure may reduce disparities in mortality more than those focused on drivers of case fatality.

The Israeli team also investigated the impact of demographics on COVID-19 response efficacy. Their model tracks individuals based on age, neighborhood, household, and routine, allowing them to simulate the likelihood of infection spread through normal societal interactions. Using Israeli demographic data, the team has been able to model two representative cities with vastly differing population structures. Bnei Brak, where 50% of the population is under 18, is ranked among the lowest socio-economic levels assessed by the government, while Holon's population is comparatively older and wealthier. Members of the synthetic population of each can then be tracked as they encounter each other, spread, and progress through individualized outcomes.

Harnessing this model, the team sought to determine how various vaccination and intervention strategies might best protect each population. Four main strategies were tested, based on a set daily vaccination rate: vaccination of any eligible individual at random, vaccination of eligible individuals by household, vaccination of all individuals in a household, and vaccination by neighborhood. Three sub-strategies were modeled for each- by oldest age group to youngest (descending), youngest age group to oldest (ascending), and with no consideration for age. The team further investigated the impact of household isolation for symptomatic individuals, and rapid testing at kindergartens and schools to screen for asymptomatic students. Results showed that individualized approaches based on demographics mattered, with interventions focused on younger populations having a greater impact on case reduction in Bnei Brak, for instance. Under all of the tested scenarios, ascending strategies decreased the total number of cases, and descending strategies were more favorable in limiting the number of critical cases, as expected. While the strategy “General descending” or “Household descending” allowed for the minimum number of critical cases, “Neighborhood descending” allowed for a low number of critical cases while keeping the number of total cases relatively low. Thus, even though neighborhood strategies weren’t optimal in each criterion on its own, “neighborhood descending” allows the best result on limiting both criteria.

Each team’s work impacted their geographic communities as well as their academic ones. The Tel Aviv team presented its work to the ZATAM (Israel’s national outbreak response committee) and advised municipalities during the outbreak, while the Northwestern team provided weekly forecasts of hospital capacity needs at the regional level in Illinois and Chicago. Both teams published several papers, and presented their work in several forums, a full listing of which can be found below. The Northwestern team also included a number of trainee scientists in their research, with two trainees serving as first authors on resulting publications, and a group of undergraduates developing the sentinel surveillance project prototype.

Publications (PIs bolded, trainees underlined)

Kohanovski, I., **Obolski, U.**, & Ram, Y. (2022). Inferring the effective start dates of non-pharmaceutical interventions during COVID-19 outbreaks. *International Journal of Infectious Diseases*.

Feng, A., **Obolski, U.**, Stone, L., & He, D. (2022). Modelling COVID-19 Vaccine Breakthrough Infections in Highly Vaccinated Israel-the effects of waning immunity and third vaccination dose. *Plos Global Public Health*.

Ben-Zuk, N., Daon, Y., Ben-Adi, D., Sasson, A., **Nevo, D.**, **Obolski, U.** Assessing COVID-19 vaccination strategies in varied demographics using an individual-based model. *Frontiers in Public Health*.

Holden TM, Simon MA, Arnold DT, Halloway V, **Gerardin J.** Structural racism and COVID-19 response: Higher risk of exposure drives disparate COVID-19 deaths among Black and Hispanic/Latinx residents of Illinois, USA. *BMC Public Health*. 2022; 22:312.

Goyal S, **Gerardin J**, Cobey S, Son C, McCarthy O, Dror A, Lightner S, Ezike NO, Duffus WA, Bennett AC. SARS-CoV-2 Infection Among Pregnant People at Labor and Delivery and Changes in Infection Rates in the General Population: Lessons Learned in Illinois. *Public Health Reports*. 2022; 137(4): 672-678.

Runge M, Richardson RAK, Clay P, Eagan A, Holden TM, Singam M, Tsuboyama N, Arevalo P, Fornoff J, Patrick S, Ezike NO, **Gerardin J.** Modeling robust COVID-19 intensive care unit occupancy thresholds for imposing mitigation to prevent exceeding capacities. *PLOS Global Public Health*. 2022; 2(5): e0000308.

Presentations

Causal Inference for Infectious Diseases (**Nevo, D.**) , AI Week, virtual, February 2022

You can't always get what you want: estimating vaccine causal effects from observational data (**Nevo, D.**), 1st conference of the Tel Aviv University Center for Combatting Pandemics (TCCP), Tel Aviv, March 2022

Mathematical modeling to inform policy: COVID-19 in Illinois. 3rd International Conference on Statistics: Theory and Applications, plenary talk. July 2021.

Structural Racism And Covid-19 Response: Higher Risk Of Exposure Drives Disparate Covid-19 Deaths Among Black And Hispanic/Latinx Residents Of Illinois, USA. INFORMS Annual Meeting. October 2021.

Structural racism and COVID-19 response: Higher risk of exposure drives disparate COVID-19 deaths among Black and Hispanic/Latinx residents of Illinois, USA. American Society of Tropical Medicine and Hygiene 70th Annual Meeting, Baltimore MD. November 2021. Presented by trainee Tobias Holden.

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