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Can we use the lessons of the pandemic to face the next humanitarian crises, now? Perspectives for Mathematical Modelling on Population Health and its Determinants

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Abstract

The COVID-19 pandemic is only one devastating example of the pressing need to effectively apply science to solve real-world problems in today's global environment. Mathematical modelling applied to population health research and management is one effective tool to bridge that gap, but we are not using it to its full potential. This article presents a reflection on some lessons from successfully applying mathematical models to guide decision-making during the COVID-19 pandemic in Costa Rica. We assembled an inter- and cross-disciplinary team with three key characteristics: robust cutting-edge technical skills for mathematical modelling, an effective pathway to communicate with the decision-makers, and the capacity to translate what the decision-makers needed to know into parameters in the model, and vice versa. Lessons from this experience can guide on how to transform the use of mathematics to understand and improve population health and its determinants, to help us face the next humanitarian crises, now.

Keywords: Mathematical models; Evidence-based policy making; Population health; COVID-19

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¿Podemos usar las lecciones de la pandemia para enfrentar las próximas crisis humanitarias, ahora? Perspectivas para la modelación matemática de la salud de la población y sus determinantes

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Resumen

La pandemia de COVID-19 es solo un ejemplo devastador de la necesidad apremiante de aplicar la ciencia de manera efectiva para resolver problemas del mundo real en el entorno global actual. El modelado matemático aplicado a la investigación y gestión de la salud de la población es una herramienta eficaz para cerrar esa brecha, pero no lo estamos utilizando en todo su potencial. Este artículo presenta una reflexión sobre algunas lecciones de la aplicación exitosa de modelos matemáticos para guiar la toma de decisiones durante la pandemia de COVID-19 en Costa Rica. Reunimos un equipo interdisciplinario y transversal con tres características clave: sólidas habilidades técnicas de vanguardia para el modelado matemático, una vía efectiva para comunicarse con los tomadores de decisiones y la capacidad de traducir lo que los tomadores de decisiones necesitaban saber en parámetros en el modelo y viceversa. Las lecciones de esta experiencia pueden orientar sobre cómo transformar el uso de las matemáticas para comprender y mejorar la salud de la población y sus determinantes, para ayudarnos a enfrentar las próximas crisis humanitarias, ahora.

Palabras clave: Modelos matemáticos; Elaboración de políticas basadas en evidencia; Salud de la población; COVID-19

1. Introduction

Although research is always aimed at providing answers, when applied to population health, we need it to provide answers that will help us solve the problems people are facing today or in the near future. Worrisomely, we do not need to go far to find a series of immediate pressing issues the world needs to find answers for. The COVID-19 pandemic showed the pressing need to effectively transform the way we apply science to solve real-world problems in today's global environment. Unfortunately, even after much progress, nearly all countries in the Americas continue to report disruptions to essential health services, similar to what was reported in the first year of the crisis [5]. Only ten countries in the region report to have allocated additional funding for longer-term health system recovery and resilience, and just five have plans in place [5].

This article presents a reflection on the use of scientific methods, specifically mathematical modelling, to help solve real-world problems. It reflects on lessons from a successful inter-institutional and transdisciplinary team experience in Costa Rica of applying mathematical models to guide decision-making during the COVID-19 pandemic. It discusses how these lessons can guide us in transforming the use of science to understand and improve population health and its determinants and to help us face emerging challenges, such as reaching the targets of the 2030 Sustainable Development Goal Agenda.

2. Materials and methods

During COVID-19 in Costa Rica, we were able to assemble an inter- and cross-disciplinary team to model the trajectory of epidemiological and health services variables related to the spread of the disease and to inform the impact of diverse types of sanitary measures [6]. Our team was comprised of experts from an array of backgrounds, including mathematics, biostatistics, public health, health services research, and economics, among others. Perhaps the most unique aspect of this team was the diversity of roles the members played in the pandemic response, combining academics with public health officials and policy advisors working together in the same team. The team was able to leverage and build upon three fundamental and synergic capacities:

1. A robust, cutting-edge technical mathematical model.
2. An effective pathway to communicate with the decision-makers.
3. An effective capability to translate what the decision-makers needed to know into parameters in the model, and vice versa.

Certainly, other remarkable approaches also succeeded at providing robust modelling data to decision-makers with a direct impact on the pandemic response. For example, the Ontario Modelling Consensus Table in Canada was developed early in the pandemic in the form of an explicit partnership between provincial decision-makers and a group of largely university-based modelers [4]. One of the differences in our experience was that we did not only advise public health officials, but we teamed up with them. That gave us the advantage of working together to understand the questions we needed to answer, its translation into parameters of the model, and access the necessary data to run that model. Despite shortages of several resources, this collaboration was recognized in Costa Rica and abroad as a remarkable success. Some could argue that this experience was only possible due to the unique context of the pandemic. While no specific funding source was available, the three main institutions - the University of Costa Rica, the Ministry of Health, and the Pan American Health Organization/World Health Organization committed in-kind resources to the development of this work. Team participants also donated their time, motivated by a strong sense of duty. Other extraordinary resources that were made available to the team included access to first-hand COVID-19 data from the Ministry of Health and the Costa Rican Social Security Fund and some additional computing capacity. However, with the pandemic fading away, four crucial elements that the team requires for making such an extraordinary endeavor possible are vanishing:

1. Funding.
2. Continuous access to crucial data.
3. State-of-the-art computer processing capacity.
4. A defined roadmap to keep those three fundamental success factors together.

From early 2020, defeating the pandemic was the unifying roadmap needed to align everyone's efforts toward saving lives. But after the first two years, this driving force started to fade. The resources were no longer available in the same fashion, and that has been so far, at least part of the reasons for this venture to have stalled. But what would it take to rebuild and even multiply such strong partnerships to provide answers to the challenges of the next pandemic? As it was pointed out above, the three fundamental components of success were:

2.1. Technical Strength

Having a robust mathematical model was, of course, a requirement, but not an obvious one. Without strong technical capacity, the whole process becomes either flawed or inconsequential. Worryingly, during the pandemic, there was no shortage of underwhelming models and flawed technical proponents contributing to a wide range of scientific or pseudo-scientific fora, inflamed by unprecedented attention from all sorts of media. During the pandemic, not as many models as one would expect were actually robust enough to provide valid evidence. Misleading results from poor technical analyses can lead to counterproductive effects. Furthermore, the fact that so many flawed analyses received as much attention as those that were technically sound should make us reflect.

2.2. An effective pathway to communicate with the decision-makers

It is not common for decision-makers in the public sector to team up with researchers to unveil the potential of real-life applied research. By contrast, this is common practice in other fields, such as knowledge-based industries, in which applying research findings can lead to key competitive advantages. Some could argue that clinical health care does incorporate a high rate of cutting-edge research in everyday practice. Here the decision-makers, the physicians, work closely with those researchers pushing forward knowledge boundaries, or they are those researchers themselves. This is not the case for public health. And there is the issue of data. There are several barriers for researchers to gain access to population-level data, at least when the research is not for commercial purposes. Public officials should work together with research teams to provide them with access to data that can provide useful answers in return.

2.3. An effective capability to translate what the decision-makers needed to know into parameters in the model, and vice versa

This is an element as important as the previous two but often overlooked. It is perhaps taken for granted, or misunderstood, or researchers may have difficulties properly seeing from the perspective of policymakers. Often, asking the right questions is as important as giving the right answers. The problem is complex and entitles several challenges. On one hand, it is not always evident what the decision-maker really needs to know, not even for themselves. For example, while modelling COVID-19 transmission trends, the most common question was when to expect the infections to peak. Our answer was simple: we do not know. And we did not care much either, because the timing and intensity were dependent on the actions that decision-makers and the general population would take. The truly useful questions were about the comparative impact of alternative sanitary measures, combined with other factors. For example, before landing on the analysis depicted in [6] we stumbled through a series of forecasted scenarios without a clear purpose. We were asked about the impact of removing masks or a series of partial lockdowns when no one was actually considering those measures. Generally, decision-makers do not know what models are for and researchers do not know what decisions they are informing. Only when we finally understood what the authorities really needed to know and could effectively translate it into parameters of the model, we were able to really inform decision-making. But here comes the second challenge, it is not always evident how or whether the questions can be translated into variables of the model. For example, in [3] we modeled the introduction of a new variant, Delta, to Costa Rica. Most if not all the models that we saw at that stage were limited to increasing the rate of infection to the circulating variant of the virus. But a new variant has different severity, mortality, probability of hospitalization, immunity from different types of vaccines or from prior infection, etc. Many of those models were, therefore, not describing the emergence of a new variable. We adjusted every one of the parameters in the model based on available information. And then, there is a third challenge to be considered, to understand how the results can be translated into public health measures. When the authorities were informed about the predicted timing of that peak in infections, then what? Were they supposed to prepare to de-escalate hospital capacity after that date? Or anticipate lifting restrictions? Or simply wait and see if the prediction was right, which was usually the actual response. In our case described in [6], we directly tested the impact of two sets of sanitary measures to restrict human mobility, which finally led to an informed decision from the health authority. Furthermore, in [3], we described the comparative impact of two different vaccination strategies, considering both the availability of doses and population intake. In a moment of uncertainty from international reports of a devastating new variant, the analysis showed how a sustained vaccination effort could pay off in terms of morbimortality and cost for the health care system.

3. Discussion

3.1. Why did the formula of success stop working? What do we need to keep it running?

With the retreat of the pandemic, the driver that fueled such strong collaboration is no longer there to keep the elements together. Institutions have other pressing priorities, researchers have new commitments, and the return of investing time and effort in terms of scientific and media attention has dropped dramatically. The answer is simple, we need a new pandemic to be able to replicate such a successful formula. But don't we already have a number of pandemic-like public health and humanitarian emergencies here or in the making? Why are we not acting on them now? To extrapolate the experience of the COVID-19 pandemic may sound adventurous because the confluence between scientific and political needs may not repeat in such a manner for a long time. But the needs are still there, and we should try to find a way to make them coalesce to address current pressing issues, and lessons from COVID-19 may help. As Diez Roux [2] recognized early in the pandemic, the crisis created unanticipated opportunities to illuminate the way forward to unleash our power as a society to generate lasting transformation.

3.2. What answers do we need for the future... now, on population health and its determinants?

Here is a discretional list of pressing public health and humanitarian challenges that the strategic use of mathematical modelling can help to address:

1. We need cutting-edge mathematical models to simulate pandemics on a global scale. We cannot just wait for the next pandemic to start from scratch again.
2. We need models to study other epidemics and outbreaks that are already here: vector-borne diseases that will only rise due to climate change or the public health emergency of antibiotic resistance, to mention only a couple of them.
3. We also need mathematical models to study non-communicable diseases (NCDs), such as the current pandemic of child and adolescent obesity, depression, and suicide.
4. We need a much better understanding of the drivers and the determinants of interpersonal violence, substance abuse, and the developmental impact of social media.
5. We need much better and more sophisticated mathematical models to optimize health service delivery and anticipate patient flows, supplies, distribution, and demand for the healthcare workforce.
6. We can use mathematical models to understand the interrelation between social, economic, and cultural factors with population health, to better understand and enhance people and community engagement in health, and to address, for instance, the social determinants of health.

The Sustainable Development Goals (SDGs) are a significant guide to finding these priorities. Although even before the pandemic, the world was not on course to meet the SDGs, COVID-19 meant a sizable reversal in progress toward the 2030 Agenda. Benedek et al. [1] estimated that some selected countries will have to spend an average of 14 percent of GDP additionally every year from now to 2030 to meet the SDGs, some 21 percent more than before the pandemic.

And although many are distracted by the SDG 3 “good health and well-being,” the truth is that population health is represented in practically every one of the 17 SDGs. Let’s think about ending poverty, proving quality education, reaching zero hunger, accessing clean water and sanitization, decent jobs, etc. All of them represent fundamental determinants of health and well-being. And what are our sophisticated mathematical modeling capacities doing to help achieve these goals? Let’s take SDG 1, for example, “End poverty in all its forms everywhere by 2030.” The target of zero hunger by 2030 was defined by linearly projecting the trend observed immediately before 2015.

What if we could do better projections? What if we could model accelerators and bottlenecks and anticipate how factors such as climate change, global economic activity, food prices, or humanitarian investment will impact the course of poverty towards 2030? This would demand an impossible amount of data, computing and processing capacity, funding, and talent that we do not have. Or we do have them, but we need extraordinary events such as the pandemic to unleash them and put them to work together?

On March 9, 2021, The Japan Times announced that Fugaku, the fastest supercomputer on earth, was put to work on COVID-19 research.[7] At the same time, global tech companies such as Google and Facebook made publicly available part of their big data on human mobility to support the fight against COVID-19. The world poured funding and talent to solve the pandemic of the century. Even without a pandemic, computer processing power is expected to double about every two years, according to Moore's law, and breakthrough developments such as quantum computing are around the corner. Big data grows explosively at the time that new tools for analyzing it become available, such as machine learning and other types of artificial intelligence technologies.

We are facing explosive growth in opportunities. If we could only capitalize on them. We need partnerships, and investment to bring talent and resources, we need to share a vision, and most of all, we need the ingenuity to believe that we can. We can perhaps dream about reaching the 2030 agenda or saving our collapsing ecosystems from climate catastrophe.

There are several risks on the horizon. Take data access, for example, is it acceptable that most big data is only available to private companies who own it? It seems like privacy issues only apply to non-commercial research. We need regulation, and we need to innovate to find ways to give access to these powerful resources to the people who can deliver knowledge that will benefit us all. As the pandemic showed us, we need multilateralism and bold partnerships to accelerate innovation to reach breakthrough solutions, and these cannot be taken for granted.

To provide the answers that we need for tomorrow, we need to start thinking one step ahead of what is possible today with the tools that are starting or about to come.

We have the needed data and processing capacity, and we can pool the funding needed. We just need to put them in the hands of capable, talented teams that can demonstrate technical excellence, close communication with decision-makers, and can effectively translate what the decision-makers and researchers need to know to generate the correct answers; useful, applicable solutions that will directly improve lives.

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