The need for a complex systems model of evidence for public health

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Despite major investment in both research and policy, many pressing contemporary public health challenges remain. To date, the evidence underpinning responses to these challenges has largely been generated by tools and methods that were developed to answer questions about the effectiveness of clinical interventions, and as such are grounded in linear models of cause and effect. Identification, implementation, and evaluation of effective responses to major public health challenges require a wider set of approaches[1,2] and a focus on complex systems.[3,4]

A complex systems model of public health conceptualises poor health and health inequalities as outcomes of a multitude of interdependent elements within a connected whole. These elements affect each other in sometimes subtle ways, with changes potentially reverberating throughout the system.[5] A complex systems approach uses a broad spectrum of methods to design, implement, and evaluate interventions for changing these systems to improve public health.

Complex systems are defined by several properties, including emergence, feedback, and adaptation.[3] Emergence describes the properties of a complex system that cannot be directly predicted from the elements within it and are more than just the sum of its parts. For example, the changing distribution of obesity across the population can be conceptualised as an emergent property of the food, employment, transport, economic, and other systems that shape the energy intake and expenditure of individuals. Feedback describes the situation in which a change reinforces or balances further change. For example, if a smoking ban in public places reduces the visibility and convenience of smoking, and this makes it less appealing, fewer young people might then start smoking, further reducing its visibility, and so on in a reinforcing loop. Adaptation refers to adjustments in behaviour in response to interventions, such as a tobacco company lowering the price of cigarettes in response to a public smoking ban.

Rhetoric urging complex systems approaches to public health is only rarely operationalised in ways that generate relevant evidence or effective policies.[1,6] Public health problems that emerge as a property of a complex system cannot necessarily be solved with a simple, single intervention, but the interacting factors within the system can potentially be reshaped to generate a more desirable set of outcomes.[7,8] Achievement of meaningful impacts on complex multicausal problems, like obesity, requires more than single interventions, such as traffic light food labelling or exercise on prescription, many of which require high levels of individual agency, have low reach and impact, and tend to widen health inequalities.[9–11] Shifts within multiple elements across the many systems that influence obesity are

required, some of which might only have small effects on individuals but can drive large changes when aggregated at population level.[12]

Although randomised controlled trials of individual-level interventions are relatively straightforward to do, it is often impossible to randomise a population-level intervention, such as the introduction of a national tax on sugar-sweetened beverages, or the multiple factors that support cycling, such as physical infrastructure, spatial planning, and integration with public transport. Approaches to research that aim to understand single components within systems,[13] or attempt to factor out the system context using randomisation and control, are thus of limited use for identifying how to influence complex systems to achieve improved population health and wellbeing.[14]

However, research funding, research activity, and the published evidence base are all heavily skewed towards studies that attempt to identify simple, often short term, individual-level health outcomes, rather than complex, multiple, upstream, population-level actions and outcomes. This skew echoes the prioritisation by policy makers of individual-level interventions over system-level responses, in the face of broad recognition of the need to do the opposite—so-called lifestyle drift.[15] Although it is important for public health policy to be guided by evidence, if this evidence predominantly supports individual-level interventions that have minimal reach and effect across populations, the benefits of being informed by the existing evidence base might be illusory.[16] Research on systems needs to provide policy makers and practitioners with robust and relevant evidence that takes adequate account of the real-world circumstances in which people live, policies are made, and interventions are implemented.

A shift in thinking is required, away from simple, linear, causal models, to consideration of the ways in which processes and outcomes at all points within a system drive change. Instead of asking whether an intervention works to fix a problem, researchers should aim to identify if and how it contributes to reshaping a system in favourable ways. Public health actions often exert their effects over long time periods, so researchers should track proximal, intermediate, and distal processes and outcomes to avoid mistakenly believing that interventions are ineffective, when they have merely judged them on the wrong terms and over the wrong timeframes. Researchers should also be prepared to modify interventions in response to observed changes in systems that might learn and adapt in ways that lead to dilution of the desired intervention effect.[17]

Where complex systems approaches have been used in public health research, policy, and practice they have tended to focus on describing or modelling systems. Although this focus is important, and echoes responses to other multifactorial, context-driven problems,[18] researchers now need to build on these foundations to investigate potential effects of interventions on systems (for an example, see panel). The development of robust tools, by use of a broad, multidisciplinary suite of methods for both intervention research and evidence synthesis, is needed to support effective policy responses.

Research funders will need to rebalance the distribution of projects that they sponsor, with increased support for evaluations of public health interventions that

take account of complexity and systems. Researchers will have to develop knowledge and skills to match, requiring substantial capacity building over an extended period.[1] Several methods already exist that can be used to evaluate interventions within complex contexts.[19–26] For example, the UK's Medical Research Council has produced guidance on natural experimental evaluations,[27] studies in which the differences between experimental and control contexts are not determined by researchers, but result from policy or other interventions outside their control. Statistical methods, such as interrupted time-series analysis, can be used effectively to evaluate the impacts of such interventions over time,[28] and simulation approaches, such as agent-based modelling, can integrate diverse evidence sources, allow for non-independence and feedback, and simulate emergence.[19,29] The art and science of system-level evaluation could be developed substantially using these and other methods. Techniques from other disciplines that are more advanced in complex systems methodologies, such as economics, climate change, and urban science, also need to be adopted and adapted.[30,31]

Building capacity and funding research on evaluating interventions in complex systems will need to be supported by a favourable environment for publishing such research, including dissemination of methodological developments. Medical, health science, and public health journals will need to equip themselves with editors and reviewers familiar with the emerging science of complex systems for population health.

A complex systems approach can overcome the frustration of having "the right answers to the wrong questions"[32] for persistent public health problems. It will help to answer the recent call from the UK's Academy of Medical Sciences to reorganise the research environment to generate compelling, functional evidence for public health improvement,[1] and provides a promising way to achieve this while engaging with diverse disciplines, including the social sciences, economics, and urban planning.[33]

Achievement of this kind of shift from a linear framework to one that embraces complexity[34] will require substantial changes to the ways in which research is funded and conducted, academic work is valued, and policy is formulated. Unless the wider scientific community engages appropriately and meaningfully with these complex realities, many major public health challenges, from emerging infections to non-communicable diseases, will remain intractable. Oversimplification of these problems to fit inappropriate models of research and practice dooms such research and policy implementation to repeated failure. Existing approaches to the generation and use of evidence remain necessary, but are not sufficient. Understandably, funders are wary of supporting—and journals wary of publishing alternative kinds of research that answer novel types of questions, but it is imperative that increased, robust evidence on population-level interventions and their system effects is generated and disseminated.

There is no single pathway to reaching this goal; changing the mechanisms and infrastructure that underpin public health evidence and action is itself a complex system challenge. However, reshaping public health research, policy, and practice to incorporate complex systems approaches will be essential for improving population health and reducing health inequalities.

***Panel*: Evaluation of the UK soft drinks industry levy: a systems perspective**

In March, 2016, the UK Chancellor of the Exchequer announced a soft drinks industry levy to be introduced by April, 2018, aiming to prompt industry reformulation to reduce sugar content. The soft drinks industry levy represents a potentially major perturbation in complex and interlinked social, health, and economic systems, which is likely to trigger multiple reactions by stakeholders, potentially resulting in important impacts on diet and health. A comprehensive, system level, natural experimental evaluation of the soft drinks industry levy has therefore been planned.

A concept mapping workshop with experts from a range of academic disciplines led to generation and structuring of an initial system map, guided by predefined questions and iterative consensus building. A modified online Delphi survey refined the map, with representation from academia, public health professionals, government, civil society, and industry. Analysis identified the varying levels of agreement with the components of the map and their connections, and led to a revised version.

Data sources were identified to allow measurement of effects across a range of domains by use of interrupted time series analyses, including price, formulation, purchases, consumption, preferences, diet, and health. Qualitative enquiry, including analysis of public, media, and professional discourses, will further illuminate reported changes. Triangulation between data sources will explore the extent to which they provide a consistent interpretation and conclusions about the impacts of the soft drinks industry levy, thus strengthening causal inferences. The evaluation will use these and other approaches to the evaluation of complex systems to gain knowledge that would not be possible using traditional approaches.

Contributors

HR had the initial idea for this paper, which was the subject of a workshop in September, 2016, attended by most of the coauthors. HR wrote the first draft and all authors contributed to the development of ideas, writing the manuscript, commenting on drafts, responding to helpful suggestions from peer reviewers, and approved the final version.

Declaration of interests

We declare no competing interests.

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